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D.M. James.

Sectional Volume No. 3.

Ministry of Agriculture and Fisheries.

COLLECTED LEAFLETS

ON

CULTIVATION AND DISEASES

OF

POTATOES.

(FOURTH EDITION.)

COMMONWEALTH MYCOLOGICAL INSTITUTE
22 JUL 1976

LONDON:
PRINTED BY HIS MAJESTY'S STATIONERY OFFICE,
11–17, Hare Street, London, E.2.

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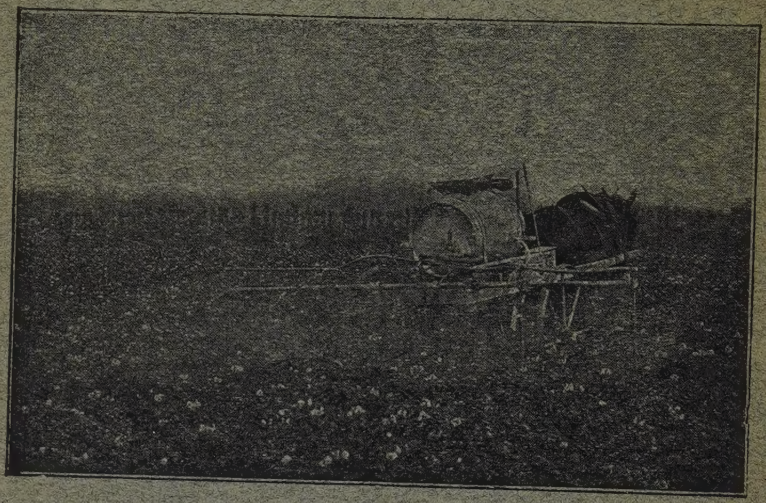

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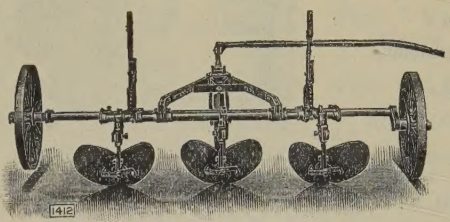

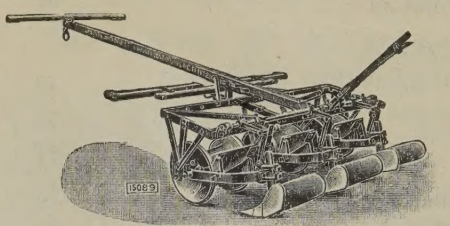

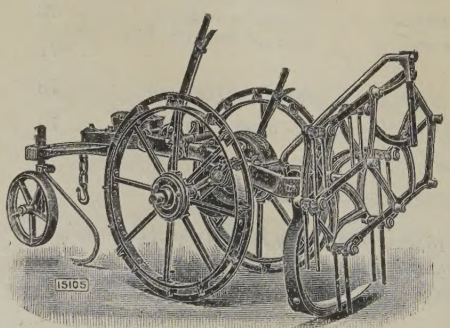

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INTRODUCTION.

The potato plant as we see it to-day is descended from wild forms which occur on the slopes of the Andes of Chile and Peru. The exact date at which it was introduced into Europe is not known, but the first record of its occurrence in England is by Gerard, who records it as growing in his garden in Holborn in 1596, and who published an illustration of the plant in his Herbal.

For the first 150 years after its introduction, the potato was regarded as a curiosity, but after the middle of the 18th century its food-value began to be appreciated and its cultivation in England and Ireland increased considerably. By 1798 its position as a staple crop was assured, and by providing an abundance of cheap and wholesome food, it was, even at that date, recognized as a substitute for bread. From that time onward the crop has increased in importance and popularity, and to-day perhaps no cultivated plant commands so much general interest.

Though its wants are few and its culture simple, the potato is unfortunately particularly subject to diseases, many of them caused by fungi and bacteria and some by so-called "viruses." These began to assert themselves early in the history of its cultivation, and references to a trouble known as "Curl" are found in literature published at the end of the 18th century. In the years 1845 and 1846 Blight swept through large areas of Europe in an intensely virulent form, and caused great losses, which resulted in famine in Ireland and the west of Scotland.

At the present time there are some seventeen or eighteen well-defined potato diseases which occur in this country, whilst there are others which remain to be investigated. Of the diseases dealt with in this volume, the first nine, being the most important, are the subjects of Leaflets. The remainder are described more briefly, although some of them may be deserving of fuller treatment when they are better understood and methods of control are known.

With regard to the relative importance of the diseases, the Potato Blight still causes more havoc than any. The notorious Wart Disease, such a potential means of loss, causes, at the present day, little actual loss. This, it should be noted, is entirely due to the Ministry's policy of compelling the exclusive use of approved immune varieties on infected land. The early work of the Ministry's officers in testing and classifying all potato varieties was of inestimable value, and Britain alone, during the time of food

shortage, was in a position to speak with certainty as to the immunity or susceptibility of all her commercial varieties. With confidence that they were immune, the Ministry itself grew thousands of tons of certain varieties for planting in infected areas. Had this knowledge not been acquired, potato growers with infected land would have been greatly handicapped and the position with regard to food might have been very different.

Two other diseases are of considerable importance in this country, viz., Leaf-Roll and Potato Mosaic. The most recent research shows that these diseases are transmissible, that the infective principle or virus is carried from plant to plant by aphides (greenfly), and that the progeny of infected plants will be diseased and remain so season after season. The use of healthy seed is therefore essential. The miserable potato plants scattered amongst healthy ones, which can be seen in any allotment, are due in nine cases out of ten to one or other of these diseases, and the trouble could be avoided entirely by the use of good seed.

Of other diseases the various forms of tuber rots and scabs are the most generally troublesome. Fortunately, potatoes in this country do not, as a rule, suffer severely from insect pests. The Colorado beetle, which plays such havoc in parts of the United States and Canada, has, up to the present, not succeeded in invading our crops. During the last few years, however, it has established itself in parts of France; and the danger of its reaching our shores and of becoming a very serious menace to potato growing in this country is now greater than ever. For this reason the Ministry's leaflet on this pest is reprinted in the present edition of the Sectional Volume of Leaflets dealing with potatoes.

London, S.W.1.

July, 1928.

POTATO-GROWING.

The potato plant is very susceptible to diseases; sensitive to climatic conditions and responsive to manurial treatment provided the chemical constituents are properly balanced. Potatoes are grown in this country by a very large number of farmers, but only those who pay attention to planting healthy seed in well-cultivated soil, well supplied with a balanced mixture of manures, gather the large crops of nine, and ten tons, or even more per acre.

All crops—both large and small—are apt to be spoilt by fungus disease (Blight) unless the foliage is protected by spraying. Such a responsive plant deserves good treatment on the lines set out in this Leaflet.

Cultivation.—As a farm crop, potatoes are grown to a greater or less extent on practically all kinds of soil, except heavy clays or on wet undrained land; but deep, rich, sandy loams, such as the Red soil of East Lothian, or well drained alluvial silts, such as the "Warp" lands of Yorkshire and Lincolnshire, are best adapted for the crop. Fen or peaty soils if well drained are also suitable, though the quality of tubers produced on such land is not quite so good. Like carrots and rye, potatoes can be grown on the very lightest sands, and on such soils the quality of the tubers is usually high while the cost of cultivation is comparatively small. There is no fixed rule as to the position potatoes should occupy in the rotation. In special cases, *e.g.*, the early potato districts of Ayrshire and Cornwall, they are grown on the same land year after year, autumn catch crops such as broccoli, rape or Italian rye-grass being the only change given. In other cases, *e.g.*, the Fen districts or on the red soil of Dunbar, they may be taken every three years, but in ordinary cases they occupy part of the root "break" and usually follow a corn crop. It may, however, be pointed out that potatoes do exceptionally well after a temporary ley or old grass, and where conditions are suitable, potatoes should be taken on at least part of any area of good grass land which is to be broken up. After really good grass the land is usually in too high condition to grow corn satisfactorily, and with proper cultivation, the decaying sod provides ideal conditions for potatoes.

Under any circumstances, potatoes demand a deep friable tilth, though a very fine condition of soil is not essential. So long as the seed is well covered, there are good opportunities for working the soil after the potatoes have been planted, and in fact, within limits, thorough cultivation after planting is beneficial. When potatoes follow a corn crop, the cultivation is similar to that for an ordinary

root crop and should begin with an autumn cleaning followed by a deep winter ploughing, with suitable cultivation in spring to secure the necessary tilth. The cultivation of leys or old grass in preparation for potatoes is not so common, and, as an extension of this practice is most desirable, mention may be made of the various ways found satisfactory.

In the case of a temporary ley, one, two, or three years old, or an exceptionally well-grazed old pasture, there is no special difficulty. As a rule the land is ploughed quite shallow in autumn, and left until early spring, when a deep cross ploughing is given, a skim coulter being used to turn the sod to the bottom of the furrow.

If farmyard manure is to be given, it is best applied on the grass before the first ploughing. If it is left to be applied in the rows, they will have to be made so deep that a good deal of the turf will be brought to the surface, and cause trouble in the subsequent cultivation.

In specially favourable conditions, as in the case of a deep uniform sand or light loam, one deep ploughing with a digging plough fitted with a good skim coulter may be sufficient. A better practice, however, is the "double ploughing" adopted on the deep alluvial soils of Lincolnshire and other districts, even where the grass is really old and not merely the comparatively loose, open turf of a temporary ley. Two ploughs follow each other; one takes off the sod to a depth of 3 or 4 in., turning it into the bottom of the deep furrow previously left by the second plough. This in turn throws the soil to a further depth of 8 or 9 in. on to the top of the shallow furrow, which is thus effectually buried and is not brought to the surface by any subsequent cultivation.

Where such a method cannot be adopted, owing either to the roughness of the sod or to the shallowness of the soil, the preparation for potatoes presents more difficulties. Under such conditions a disc harrow is a most useful aid at all stages. In some cases the sod may be thoroughly cut up by repeated disc harrowings before it is ploughed, and if the work has been well done a deep ploughing will be all that is required to prepare for the usual spring cultivation. Where a particularly thick, tough sod is encountered, the land should be ploughed shallow in early autumn and heavily rolled immediately afterwards. During winter, the sod should be torn to pieces as thoroughly as possible by repeated harrowings, disc-harrowings and whatever other operations are found to have the desired effect. Having achieved the object in view, a deep ploughing should be given, and it is desirable

to complete this in time to allow the raw soil to mellow and weather before planting-time. In the first ploughing of such land, a disc coulter will be found almost indispensable, as the rough sod drives in front of an ordinary coulter, accumulates under the beam and either forces the plough out of the ground or slips on one side in a mass which the plough cannot cover.

Taking everything into account, it is best to aim at getting the land into such a state that it can be ridged and the potatoes planted in rows, but good results are sometimes obtained on light soils by dibbling potatoes on land ploughed just as it would be for corn, or by planting the tubers in the bottom of every third furrow at the time of the second ploughing in spring. In such circumstances, the tubers should be placed under the shoulder of the previous furrow slice so as to escape damage by the feet of the furrow horse, or be dropped on the land close to the open furrow so that they are turned in by the next furrow. On a small scale the lazy bed system of Ireland may be useful, particularly where the drainage is not good, though it is not advisable to attempt to grow potatoes at all on a really badly drained soil.

The advantage of having potatoes in drills is particularly marked in the case of foul soils. Given good weather conditions, much can be done to clean the land before the young shoots appear. The usual process consists in harrowing down the ridges with either "saddleback" or chain harrows, scuffling or grubbing between the rows and then earthing up with a ridging plough. This series of operations is repeated as often as thought desirable until the potatoes are just appearing at the surface, and the result is not only suppression of weeds at a comparatively small cost but the reduction of the soil to a fine uniform tilth even if it was in a rather rough condition when the crop was planted. If good seed of a strong, vigorous variety has been selected and the manuring is adequate, further cleaning will soon be impossible and unnecessary, as no crop in general cultivation is so well able to smother out weeds of all kinds as a really good crop of potatoes.

Manuring.—The potato needs a liberal supply of air to the roots and underground stems, in order that tubers may form easily; it also needs a sufficient supply of moisture. Farmyard manure, in that it has physical effects on the soil which help the air and water supply to the roots of the plant, should remain the basis of manuring for potatoes. Dung was formerly used at the rate of 20 tons per acre for the potato field, but no more than half quantities can be

spared for potato fields at the present time, and the balance is made up by artificial manures drawn in varying quantities from the three groups of fertilizers.

Nitrogen.—Of the nitrogenous manures, the commonest is sulphate of ammonia. Investigation has shown that 1 cwt. of sulphate of ammonia per acre applied to experimental plots has increased the yield by 20 cwt. per acre: further additions secure increases of a lesser quantity so that ultimately a point is reached when further dressing might prove unremunerative. The application of 2 cwt. per acre is quite common, though 3 cwt. and even 4 cwt. per acre are sometimes applied when potato prices are high. Nitrate of soda, nitrate of lime and calcium cyanamide have not been much used either in the field or experimentally, but presumably these fertilizers are about equal, nitrogen for nitrogen, to sulphate of ammonia.

Phosphates.—Formerly, it was accepted that potatoes should be generously manured with phosphatic manures, of which perhaps superphosphate was the more common, but present opinion on the subject is by no means unanimous. Experiments supply evidence of the advantage of using superphosphate on certain classes of soils, as, for example on the black fens, but experiments on the silt soils of Kirton, Lincs., whilst pointing to the necessity of superphosphate for the potato crop, showed that it should not be used in larger quantities than 2 cwt. per acre. Larger quantities not only did no good, but were actually harmful. Future experiments in other counties and on other soils may show these results to be unusual, so that for the present it would be wise to use superphosphate in lesser quantities than formerly, say 3 cwt. or less per acre for every 1 cwt. of sulphate of ammonia applied.

Potash.—The importance of potassic manuring has long been recognized. Where farmyard manure is liberally supplied, it may not always happen that potassic fertilizers produce any great effect. Farmyard manure contains an appreciable quantity of potash, and, in a 15-ton dressing, there is as much as is necessary, though in a less available form. With smaller quantities of farmyard manure, or where the manure is not well made, the deficiency should be made good by using one of the artificial fertilizers. The sulphate and muriate usually give smaller increases in yield, but the tubers fertilized with the sulphate contain chemically more dry matter per ton and more starch in the dry matter used, and such tubers always give a better cooking quality. Where dung is used, 1 cwt. of sulphate of potash—or without dung 2 cwt. of sulphate of potash—is quite a normal dressing per acre of land.

The low grade potash fertilizers are, as a rule, less effective than the muriate or the sulphate.

Thus it appears that a normal dressing for potatoes per acre would be:—

12 tons dung,
supplemented by
1 cwt. sulphate of ammonia.
3 cwt. superphosphate,
1 cwt. sulphate of potash;
or without dung,
2 cwt. sulphate of ammonia.
6 cwt. superphosphate.
2 cwt. sulphate of potash.

Magnesia.—Claims are often made that increased crops have been obtained by the use of magnesium sulphate, but there is no experimental evidence to show that it is effective.

Choice of Variety for Seed.—In the cultivation of potatoes, the importance of good "seed" cannot be over-emphasized. Most growers realize the importance of planting only true stocks of potatoes in order to avoid the disappointment and loss which often result from the growing of impure seed. Arrangements are made every year for the official inspection of growing crops with a view to the issue of certificates that the crops are true to type and reasonably free from rogues, and purchasers who desire to ensure that they will be planting pure seed should specify in their orders that seed from crops inspected under these arrangements is required. It should be remembered that on every sale of potatoes for planting, the seller is required to furnish the buyer with the number of the certificate relating to the potatoes sold and with a written statement containing the following particulars:—

(*a*) The name and address of the seller. (*b*) A statement as to whether the potatoes are Class 1 (Scotch), Class 1 (Irish), Class 1 (English once grown) or Class 2. (*c*) The variety. (*d*) Size and dressing.

Sprouting.—Having obtained good seed potatoes, it is important to store them under conditions where deterioration will not take place, but rather where the seed can send out its sprouts early in the season under the most favourable conditions. Particulars as to the storage and sprouting of seed potatoes are set out in Leaflet No. 362.

Potatoes vary greatly as regards cropping capacity, cooking quality, disease resisting power and earliness. Care should be taken to select varieties which suit the conditions under which they are grown, and the purpose for which they are intended. It is impossible to mention more than a

few of the best and well-known varieties, but from these a selection might be made to suit almost any conditions or market. It is perhaps necessary to add that the same variety is often sold under several different names. In the following notes the best known varieties of each type or group are mentioned.

First Earlies.—*May Queen* and *Duke of York* (syn. *Midlothian Early*) (*see* Fig. 1) are two favourite varieties for garden cultivation. They are very early and of good quality.

Ninety-fold is a heavy cropping variety, though the tubers are rather watery, and readily suffer from handling. It is fairly early, and should be lifted in good time, as it is very susceptible to ordinary potato disease.

Sharpe's Express (*see* Fig. 2) is a good cropper. The tubers are kidney-shaped and of excellent quality. If lifted too early, a large proportion of the crop will be small, but where extreme earliness is not required the variety can be recommended.

Epicure from the time of ripening is strictly speaking a second early, but it is a quick grower, and a large proportion of the tubers, even when lifted early, are of marketable size. It resists potato Blight well. It should, as a rule, be marketed in good time, as the tubers if left to mature become rough and coarse, and are not then readily disposed of. The variety on a field scale is grown more extensively perhaps than any other early variety.

Eclipse, like *Epicure*, is one of those quick-growing second earlies which produce good large crops which can be marketed in an unripe condition.

Boston Kidney (syn. *Dargill Early*) is immune from Wart Disease and can be planted on infected land. The tubers of this variety are kidney shaped, flesh lemon coloured, quality good. It is a favoured variety with the Cornish grower for the early markets.

Snowdrop (syn. *Witch Hill*) produces heavy crops of perfectly white-fleshed, good quality tubers. It is rather susceptible to the ordinary potato blight but immune from Wart Disease.

Second Earlies.—*British Queen* combines cropping power with cooking quality but the crop should be lifted comparatively early to avoid loss by disease.

Great Scot (*see* Fig. 3), a white round variety, produces very heavy crops of good potatoes. It has become a great favourite. It is not affected by Wart Disease but is susceptible to the ordinary potato Blight. On this account it should be lifted comparatively early or sprayed in July with either Bordeaux or Burgundy mixture.

Fig. 1.—Duke of York.

Fig. 2.—Sharpe's Express.

[*To face page* 10.

FIG. 3.—Great Scot.

FIG. 4.—Majestic.

Ally is an oval potato with a nice russety skin. It crops heavily, but the quality of the tubers is only fair. It is immune from Wart Disease.

Mid-Season or Early Main Crop Varieties.—*King Edward* is a well-known oval potato with pink patches. It produces heavy crops of good quality when grown on deep rich and rather moist land, but is apt to be disappointing under dry conditions. It is susceptible to Wart Disease and to potato Blight, and should be lifted comparatively early, though the tubers if properly stored keep very well. A red sport known as *Red King* is also grown.

Majestic (*see* Fig. 4) is a very heavy cropping variety of white, kidney-shaped, thin-skinned tubers, immune from Wart Disease.

Main Crop or Late Varieties.—*Arran Chief* produces round tubers of good size and quality.

Kerr's Pink has a vigorous haulm and produces large crops of round, pink tubers of excellent quality, shaped somewhat like *Arran Chief*. It is resistant to Blight.

Field Marshal is a variety similar to the older *Up-to-Date* but the tubers differ in having a russety skin.

Wart Disease.—Where Wart Disease exists, the planting of potatoes is subject to restrictions under an Order of the Ministry. Before planting any potatoes, growers should ascertain whether those restrictions apply to their land. Further information on this subject may be obtained from the Ministry, 10, Whitehall Place, London, S.W.1.

That immune varieties give excellent crops of sound tubers when planted on badly infected land is an established fact, and only disaster would result from planting varieties susceptible to this disease on such land.

Planting.—No potatoes may be planted in England and Wales (except seed saved from the crop grown on the premises in the previous year) unless they are the subject of a certificate in one of the forms prescribed in the Wart Disease of Potatoes Order, and growers should take care to see that they have been furnished with the number of the certificate by the person from whom the seed was obtained. (*See* p. 9.)

Potatoes grown outside Great Britain and Ireland must not be planted in England and Wales except under licence from the Ministry.

Time of Planting.—Potatoes should be planted in spring, as soon as a good tilth can be obtained. April is generally

a suitable month, but planting is sometimes possible towards the end of March, while good returns are not infrequently obtained from seed planted in May. When, however, no special precautions—such as boxing—are taken to preserve the first sprouts, it is advisable to plant the potatoes so that they shall, as far as possible, make their first growth in the soil. A good covering of soil will protect the sets from frost, even when planted as early as the end of March, but as soon as the weather becomes fairly mild, part of the covering should be removed by harrowing, as weak and spindling sprouts result if they have to push their way through a considerable thickness of soil before reaching the light.

Depth of Planting.—As to the proper depth to plant, a great deal depends upon the character of the soil. Where the soil is loose and friable it is possibly advantageous to plant fairly deeply. When dung is applied in the row, the danger of the sets being covered too much is minimized, but, when potatoes are planted without dung in the row, there is considerable risk of their being covered too deeply, especially on the heavier class of soils; on such land the use of dung in the drills is to be recommended.

Distance Apart.—The width between the rows, and the distance between the sets in the rows, also depend upon local conditions, but, in general, 26 in. between the rows and 15 in. between the sets will prove satisfactory. On the other hand, on some soils and in some localities, 12 in. or even less between the sets has yielded a better crop.

With First Early varieties, the distance between the rows may be 20 to 24 in., and between the sets in the row, 10 to 12 in., though in the Penzance district they are planted much more closely.

Spraying.—The object of spraying potatoes is to reduce the loss caused by the ordinary potato disease or Blight (*Phytophthora infestans*),* and it must be made clear that the extent of the damage done by this disease cannot be measured simply by the proportion of tubers found to be diseased when the potatoes are lifted. The disease first makes its appearance on the leaves or sometimes on the stalks, usually between the end of June and the beginning of August. If the variety grown is not one which resists the disease, and if other conditions are suitable—particularly if the weather is moist and warm—the whole of the haulms may be killed off in a few weeks, with the result

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* *See* Leaflet No. 23, *Potato Blight and its Prevention*, included in this Volume (p. 25).

that, instead of growth extending well into October, no addition to the weight of tubers takes place after, say, the beginning of September.

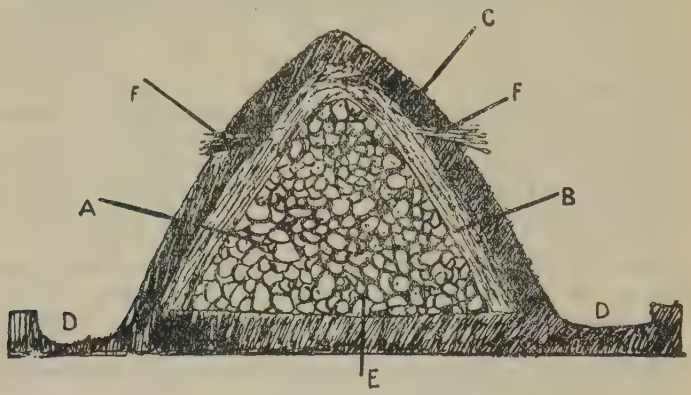
As a general control measure, spraying with Bordeaux or with Burgundy mixture is strongly recommended as the best preventative of an attack of Blight. It is realized, however, that in some districts spraying is very much more important than in others. In some of the drier counties on the east coast and north-east, the question as to whether taking a number of seasons together, spraying is worth the labour and expense incurred and is a sound commercial proposition, is still undecided. Some of the larger growers in Lincolnshire, however, are now making a practice of dusting their potato crops with a copper-containing powder.

There are, however, certain special circumstances when spraying is inadvisable and may be even harmful, at any rate when Burgundy Mixture is employed, *e.g.*, in the neighbourhood of large industrial centres and after a severe attack of *Aphis*.

Time to Lift Potatoes.—It is highly important that potatoes should be lifted as soon as they are ripe. It has been demonstrated repeatedly that, if attention is given to this point, comparatively healthy crops can be obtained even from those varieties which are generally regarded as being very liable to disease.

Formation of the Pit.—*The condition of the tubers* at clamping time is important. They should be put away in a dry state and as free from soil as possible. Moisture favours bacterial decay and soil hinders ventilation, hence the heat does not escape. Injured tubers, since they cause extra heating and serve as centres for the beginning of decay, should not be included more than can be helped. It is most important also to exclude, as far as practicable, all blighted tubers. Tubers likewise which have been frozen or flooded should not be clamped. If any doubt exists, or if a certain proportion of tubers are believed to be injured, they should not be put in the main clamp, but might be pitted separately. The same advice applies to harrowings which are apt to be badly injured or touched with frost. Potatoes which have produced late growth or are still "green" (*i.e.*, immature) are particularly liable to heat. Special care is, therefore, necessary with such a crop, and subsequent inspection of the clamp should be made at intervals. Where Blackleg has been present, every precaution should be taken to reject all diseased or doubtful tubers.

With regard to the *structure of the clamp*, the following points should be borne in mind. Large clamps are liable to develop more heat than small ones, hence it is false economy to build them excessively large. Although, when other conditions are favourable, potatoes may sometimes keep well in a large clamp, as a general rule it is unsafe and inadvisable for the base to exceed 7 ft. in width. In many parts of the country a smaller size is customary. The site should be dry and well drained, and the base, if anything, slightly above the general soil level.



A. Potato Tubers stored in a Heap or Clamp.
B. Layer of Clean Straw covering Potatoes.
C. Layer of Soil covering Straw.
D. Drain dug round the Heap.
E. Showing Potatoes resting on Ground Level.
F. Ventilation by Bunches of Straw.

The general principles on which a pit, pie or clamp is made are practically the same throughout the country. The method of covering, however, varies considerably, but the following may safely be recommended. The usual roof-shaped pie is covered with a layer of straw about 6 in. thick. A plank about 1 ft. broad and from 8 to 10 ft. long is then placed along the top or ridge of the pie, and the sides, to the edges of the plank, are covered with an inch or two of soil. The plank is then moved along and another length is covered with soil. In this way, the top of the pie is kept free from soil, thus providing for ventilation.

The soil covering should not be put on too soon. If the weather is fine and there is no appearance of severe frost, a full fortnight should elapse between "strawing" and closing in with the first covering of the soil. This allows much of the early heat (produced by respiration) to

escape. In very wet weather, the soil may be put on sooner, as it is inadvisable to close in when the straw is sodden with water.

It may be necessary to add more soil to the sides and to cover over the top later in the year, in a time of severe frost. In putting on both the first and the second or "winter coat," the north side should receive first attention.

The necessity of *ample ventilation* cannot be emphasized too strongly. In a general way it may be said that in the early part of the winter there is more risk of damage through overheating than from frost. Adequate top ventilation must, therefore, be given. The straw in places should be left exposed along the ridge, and not completely closed in. A good method is completely to protect the north side, but to leave about 10 in. open on the south. Except in the coldest localities, the winter coat need not completely cover the ridge, but an extra covering of litter (such as loose straw) is advisable.

Diseases of the Potato.—The potato crop is subject to various fungus and other diseases which may cause serious loss both in yield and quality of the produce. A number of these diseases are dealt with in the present volume.

POTATO GROWING IN ALLOTMENTS AND SMALL GARDENS.

The Soil.—Growers on a small scale can seldom choose their land, but they may do much to assist such soil as they have in producing a satisfactory crop. Heavy land should be thoroughly dug over during the autumn and winter, and should be prevented from becoming water-logged by being thrown up into ridges or narrow stretches if necessary. Twitch (couch grass), docks, nettles, or other perennial weeds should be forked out, and, if there is any reason to suspect that leather jackets (grubs of the daddy long-legs), wireworms (grubs of the click beetles), or millepedes (also known as false wireworms) are present in large numbers, the land should be repeatedly turned over whenever the weather permits. Sandy land or land with an open texture should be improved by adding anything in the nature of dead leaves, decaying vegetable matter or manure, so as to increase the humus content of the soil. Poor land should be enriched with stable or farmyard manure applied during autumn or winter, or before planting in the spring.

Lime corrects acidity and improves the texture of clay (*see* Leaflet No. 170).

Manuring.—When it can be obtained perhaps the best manure is farmyard dung, or, failing that, town stable manure. When such is available, it should be used at the

rate of 15 to 20 tons per acre—say, 2 to 2½ cwt. per rod. (A large wheelbarrow holds about 1 cwt. of well-rotted manure. If the manure is fresh and strawy, the weight will be about ½ cwt.) On heavy land, it may be useful to apply the dung when digging the ground in autumn or winter, but, on very light soils, dung may best be applied shortly before planting the tubers.

Alternatively, 1¼ cwt. of dung per rod may be applied, and at the time of planting, 2 lb. of sulphate of ammonia, 5 lb. of superphosphate and 2 lb. of sulphate of potash may be added. The artificials may be applied broadcast before planting, or in the drills immediately before planting. Where no dung is available, the quantity of the artificial manures should be supplemented by wood ashes and decaying vegetable matter. It should, however, be noted that superphosphate is an acid manure, and its constant use is apt to set up soil sourness unless otherwise corrected by the intelligent use of lime. The risks of soil acidity may be obviated by substituting for superphosphate, either steamed bone flour at the rate of 3 lb. per rod, or basic slag at the rate of 6 lb. per rod.

Basic slag is especially suitable for cold, heavy soils, but, being slower in action than the other phosphatic manures mentioned, it is best applied during the winter or early spring, before planting time arrives.

Varieties to Plant.—The selection of the best varieties to plant is a matter of some importance. Generally, growers in allotments and private gardens would need varieties which develop shapely tubers with good cooking qualities. Early varieties, especially, would be needed, as well as those which keep well without much wastage. The following are generally reliable:—

Early Varieties.—Duke of York (syn. Midlothian Early) (*see* Fig. 1 opposite p. 10), a yellow flesh kidney, and Sharpe's Express (*see* Fig. 2 opposite p. 10), a white flesh kidney, are eminently suitable for small gardens and allotments. These varieties are both susceptible to Wart Disease, so that, where the land is infected with that disease, Boston Kidney (syn. Dargill Early), a lemon flesh kidney, Snowdrop (syn. Witch Hill), a white flesh kidney, or Di Vernon, a white kidney with pink splashes, should be used.

Second Earlies.—Great Scot (*see* Fig. 3 opposite p. 11), a white round, and Arran Comrade, a white round, are both good for garden cultivation. Immune Ashleaf, a yellow flesh kidney, and Katie Glover, are gaining in popularity.

Late Varieties.—King Edward, a kidney, is still excellent for gardens and allotments. Majestic (*see* Fig. 4 opposite p. 11) is a good, heavy cropper, having white tubers, but

these must be carefully handled or losses through bruising occur. Tinwald Perfection gives a smaller crop of really nice tubers of the highest quality.

Selection and Preparation of "Seed."—An account is given in Leaflet 362 (p. 19) of the Selection, Storage and Treatment of Seed Potatoes. For planting in allotments and gardens, growers would be well advised to procure fresh seed annually, and to make sure that the seed is coming from a district known to yield good seed, free from infection by Mosaic and Leaf Roll. When the seed tubers are obtained—preferably in the autumn—they should be put into boxes and left in the sun until they get thoroughly green and hard, when they should be put away in a well-lighted shed where they will be secure from frost for the winter. They should be examined periodically to see that they are not sprouting too much—it is advisable not to let them grow sprouts more than ¾ in. in length—and this may be prevented by giving them more air or moving them into a cooler and better lighted position. If the conditions are right, each tuber should develop two or three short, sturdy sprouts. Any that do not do so, and those that develop spindly, weak, sprouts, should be discarded as unfit for planting. In these boxes, the tubers make steady and persistent growth and growers need be in no hurry to plant, until the weather and the soil have become favourable.

Tubers smaller than a hen's egg should be planted whole; those that are larger may be cut into two, or even three, pieces, but the cutting should be done so that each set has at least one good sprout and perhaps a weaker sprout or two in addition. Experiments show that, if the cut sets are allowed to remain in a shady, moist place for a few days prior to planting, most of the sets will grow and few misses will occur.

Time of Planting.—In a very few districts, potatoes may be planted in February, but March and April are the usual months, the former for the early varieties, the latter for the main crop. When the soil is reasonably dry, potatoes may be planted directly mild weather arrives in spring. If wet weather has made the preparation of the soil difficult, planting should be deferred; it is better to plant at the end of April with the land in good condition than early in March with the land in bad order.

Method of Planting.—The depth at which potatoes should be planted varies according to the soil and the climate, but, generally speaking, potatoes should be planted fairly shallowly. When the soil is light and friable, they may be put in at a depth of from 5 to 6 in., and in heavy land

about 4 in. Early potatoes should be planted at the shallower depth.

The standard distance apart at which early varieties are planted is 12 in. in the rows and 20 to 24 in. between the rows. Mid-season and late varieties may be given 15 to 18 in. between the sets, and 24 to 36 in. between the rows.

General Cultivation During Growth.—Land in which potatoes are growing should be frequently hoed during the period of growth, and all weeds should be kept down. The plants should be earthed up for the first time when they are about 6 in. high, and a second time about three weeks later. The drawing up of the soil around the plants prevents the soil from getting too wet, supports the haulm and covers over the young tubers. If the soil tends to get wet, the ridges should be made as steep as possible, but the covering of soil should only be sufficiently deep to prevent the potatoes as they form from being exposed to the air and light.

Storage.—To keep potatoes safely through the winter several points must be observed, or losses may occur through the development and spread of diseases in storage. If "Blight" in the haulm has been noticed, the haulm should be cut away and burnt, fully a week before digging commences. The dug tubers should be left on the ground to dry before being collected for storage, either in a clamp or in an underground cellar. It is advisable to sprinkle in a little lime or flowers of sulphur, or both, with the tubers. The store must be cool, dry and frost proof.

NOTE.—Under the Wart Disease of Potatoes Order of 1923, no potatoes may be planted, or sold for planting, unless they have been officially certified by the Ministry, as regards potatoes grown in England and Wales, or by the relative Department of Agriculture, in the case of Scotch and Irish seed. When purchasing potatoes for planting, growers should see that they are furnished with the number of the certificate relating to the potatoes, and with a written statement containing the following particulars prescribed by the Seeds Act and Regulations:—

(*a*) The name and address of the seller; (*b*) A statement as to whether the potatoes are Class 1 (Scotch), Class 1 (Irish), Class 1 (English once grown) or Class 2; (*c*) The variety; (*d*) Size and dressing.

Many allotment holders, on whose land Wart Disease of Potatoes has occurred in past years, appear to be under the impression that, provided no trace of the disease has been seen for two or three years, they are at liberty to plant varieties which are susceptible to the disease. This

is not the case. The Wart Disease of Potatoes Order requires that, on land on which Wart Disease has been known to appear at any time, only approved immune varieties of potatoes from stocks officially certified to be true to type and reasonably free from rogues, may be planted. The only exception to this regulation is that immune varieties saved by the plot-holder from last season's crop, may be planted. It is most important that occupiers of infected land, whether allotments, gardens, or fields should remember and act upon this regulation, for not only does the planting of susceptible varieties in infected soil render the offender liable to a penalty of £10, but it is practically certain to ensure the re-appearance of the disease which, in its turn, means a serious loss to the grower.

Further information on this subject may be obtained from the Ministry, 10, Whitehall Place, London, S.W.1.

THE SELECTION, STORAGE, AND TREATMENT OF SEED POTATOES.

Crops of 14 tons of potatoes per acre are by no means uncommon on the best lands in Lincolnshire and Cambridgeshire, whilst some allotments and gardens, growing potatoes for domestic use, produce very large crops. On the other hand, poor crops are common over the whole country in fields, private gardens and allotments. The yields from the poor crops reduce the average yield, so that for the whole country little more than six tons per acre is produced.

Heavy crops such as have been referred to are in the main the result of two factors:—

First.—The use of healthy and suitable seed tubers;
Second.—Proper cultivation and good manuring.

With the latter, we are not here concerned more than to say that, although the potato is a plant which can make effective use of very heavy manurial feeding, both artificial and farmyard, and will yield a return on good soils commensurate with the expenditure of, say, up to 15 cwt. of artificials and 15 tons of "muck" per acre, yet, if the seed be "bad" especially if it be infected with a virus disease, no amount of manure will redress the balance and make such seed yield a good return.

It is then on the choice of seed that the grower's attention should be concentrated. It is a three-fold problem which confronts him:—

First.—The choice of variety.
Second.—The size and maturity of the seed tuber.
Third.—Its health, i.e., the absence of disease in the seed tuber.

Variety.—The choice of a variety is a matter which depends on so many diverse factors, including that of the market as well as the personal predilections of the grower, that it is impossible to advise in general terms. Of late, however, yield trials of a very reliable character have been carried out by the National Institute of Agricultural Botany, and it has been shown that varieties do vary very definitely in their capacities to yield, and that the order of merit of any given series of varieties, as tried at such different stations as Ormskirk (Lancs.), Edinburgh, Truro, and Kirton (Lincs.), is within close limits the same. Hence, these results have a far-reaching application. Results are at present available for a selected number only of the First and Second Earlies, and have been published in full in the Journal of the National Institute of Agricultural Botany. In the following lists, the order of merit is that which was the most general at all stations.

Further trials are now in progress in regard to the maincrop varieties, and growers would be well advised to keep themselves informed of these results as they appear.

List of Varieties where yields have been accurately compared, in order of merit:—

First Early Varieties.

Epicure.
Duke of York. } The difference is not strictly
Sharpe's Express. } significant.
Immune Ashleaf.
America.
Ninetyfold.
May Queen.
Snowdrop.
Di Vernon.
Dunvegan.
Boston Kidney (Dargill Early).

Second Early and Maincrop Varieties.

Ally. } The difference is not strictly
King George. } significant.
Great Scot.
K. of K. }
Nithsdale. } The difference is not strictly
Arran Comrade. } significant.
Tinwald Perfection. }
Early Market. } The difference is not strictly significant.

Size and Maturity of Seed.—The size of the seed is also a matter of importance. Assuming that the stock is healthy, experiments seem to indicate that tubers weighing 2¾ to 3 oz. yield perhaps as heavily as larger tubers, and more heavily than those of a smaller size, though the crop from the latter contains a higher proportion of heavy ware. When these facts, together with the price of the seed per acre, are considered, it is found that the most profitable seed size tuber is one weighing between 1½ and 2 oz. Roughly speaking, such a tuber will pass over a 1¼ inch and through a 1¾ inch riddle. Small seed tubers are, generally speaking, less mature than big ones; hence, by the use of moderate sized seed tubers 1½ to 2 oz. in weight, the advantages of immaturity, as well as higher ware production, are obtained. If the crop is intended mainly for disposal as seed, then the grower would be wise to plant seed tubers of a larger size, i.e., up to a weight of about 3 or even 4 oz. each.

Health of Seed.—As is well known, the potato suffers from many diseases and some of them are transmitted through the seed tuber. Some diseases, such as the various forms of Scab, together with Blight, Dry-rot and so on, are evident to the naked eye on mere inspection, and growers of course will not employ obviously diseased tubers of these kinds for seed. There are, however, other diseases of a more insidious kind the presence of which cannot be detected in the seed tuber. The most important of these are the so-called Virus diseases, such as Leaf Roll and Mosaic, for they are now believed to be the principal causes of the seriously diminished and disappointing yields so often encountered. These diseases are dealt with fully in Leaflets 164 and 373*, but it may be stated here that they are more prevalent in the south of England than in the north and in Scotland, although the latter districts are by no means entirely free from them. Virus diseases are transmitted from diseased plants to healthy ones by the agency of insects such as green fly, and a plant once thus infected produces tubers carrying the virus. Such virus-infected tubers will give rise to very indifferent plants giving only a poor yield. Since, as stated, such diseases are less prevalent in the north, it is not surprising that seed derived from Scotland is superior to that saved at home in England, where the transmission of virus diseases appears to occur much more readily, and where potatoes often "degenerate" within the course of two or three years to such an extent that they become practically worthless for seed purposes.

* Included in this Volume (p. 54 and p. 68).

Storage of Seed Potatoes.—The seed tubers as soon as received—preferably in the autumn—should be placed in shallow boxes, one layer deep, if early varieties (Fig. 1 and 2), with the crown or rose end uppermost.

Where the varieties are of the main crop and late kinds, and a considerable area has to be planted, a box as shown in Fig. 4 is more suitable. Several layers of tubers may be held and the box can be carried to the field in spring without needless handling of, and perhaps injury to, the sprouted potatoes. This box will hold from 16 to 20 lb. of seed-sized tubers, and 25 to 30 boxes are necessary to hold sufficient seed for a quarter of an acre.

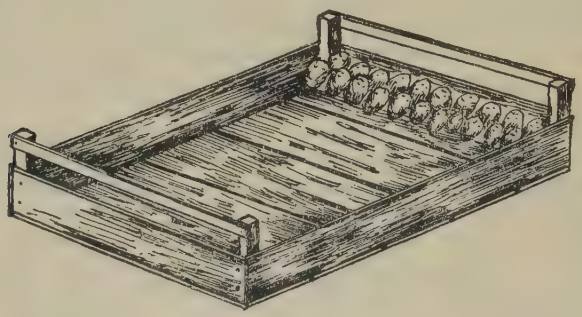


FIG. 1.—Shallow Tray for Early Potatoes. Trays can be stacked.

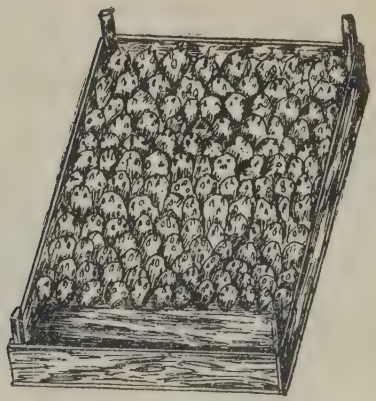


FIG. 2.—Shallow Tray with Corner Posts for stacking.

The boxes should then be placed in a cool, dry shed where light is freely admitted but frost excluded, or where, if only one or two boxes are concerned, a covering of straw or other material can be placed upon them, to protect against frost in severe weather, and removed when the danger is past.

The old system of leaving the tubers lying on the ground to "green" prior to boxing is open to certain objections, especially in a year when Blight is prevalent, as diseased haulms are often scattered in close proximity, and there is some danger of clean tubers being infected by spores lying on the surface of the soil. If the tubers are boxed and then left out there is less objection, but in a proper store with plenty of light, the tubers green sufficiently in the boxes.

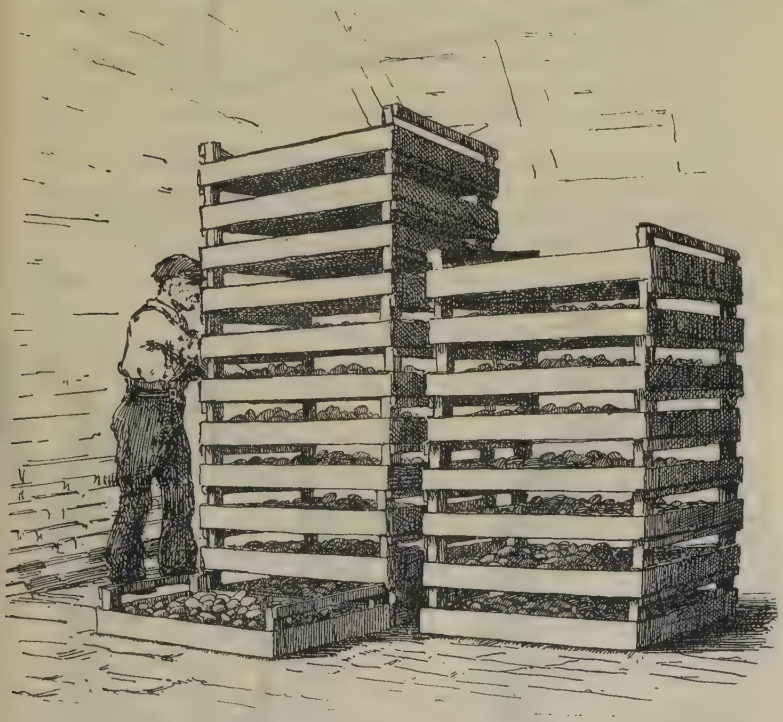


Fig. 3.—Boxes for Sprouting Potatoes.

If sufficient light has been given and proper conditions observed, not every eye will grow, but the tubers will restrict themselves to two or three leading sprouts. If, on the other hand, potato sets are kept in the dark, every eye will endeavour to produce a sprout which will be light-coloured and weakly. Where insufficient light has been given and too

many sprouts may have been produced, some of these can be reduced at the time of planting by rubbing off the weakest and retaining three of the strongest at the rose end of the tuber.

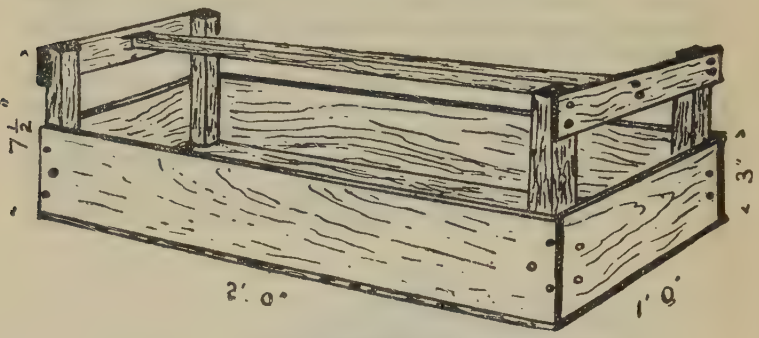


Fig. 4.—Box for Sprouting Seed Potatoes.

The sprouts at planting time should be strong and sturdy, not more than an inch long, and of a dark-green, purple or blue colour according to the variety. Tubers that develop spindly weak sprouts are unsuitable for planting.

Fig. 5.—Properly Sprouted Potato. Sprouts reduced to three.

Fig. 6.—Sprouted in the Dark. Shoots blanched and spindly. Too many Sprouts.

POTATO BLIGHT AND ITS PREVENTION.

History of the Disease.—The common potato disease known as Blight is caused by a minute miscroscopic form of vegetable life, namely, the parasitic fungus *Phytophthora infestans*. It was first noticed in Europe and North America about 1840, and by 1845 it had become widespread. In the latter year, and especially in 1846, blight was so virulent in Ireland that it caused an almost complete failure of the potato crop, with consequent famine to the inhabitants.

Since that time the disease has always been present in the British Isles, varying in intensity from year to year; more disastrous in its effects in wet seasons, less serious in dry seasons. In a wet summer, losses of more than half the crop may be caused by this disease where precautions are not taken to prevent it, and even in an average season it reduces the yield of tubers and takes a considerable toll of those that are formed by causing them to decay.

Description.—The first sign of the disease visible to the naked eye is the appearance on the leaves and sometimes on the stalks, of dark brown or blackish spots of irregular size and shape, on the under surfaces of which a delicate white mould may be seen, especially around the margin of the diseased areas. If weather conditions favour the fungus the dark-coloured patches spread rapidly and the whole of the foliage, and sometimes the stems also, soon become blackened.

Potato plants badly attacked by Blight give off a very distinct and disagreeable smell. In wet, muggy weather the whitish mould, which is a characteristic sign of the disease, may grow out from the upper as well as from the under surface of the leaves. The minute threads of which the whitish mould consists, branch like microscopic trees and produce innumerable, inversely pear-shaped outgrowths, the spores of the fungus. The spores, becoming detached from the thread-like stalks which bear them, are carried by currents of air and other means and spread the disease to any healthy potato plant on which they happen to alight. Each spore falling on a leaf or stalk gives rise to a discoloured patch owing to the product of its germination growing into and spreading through it. After the fungus has fed on the substances in the leaf, its threads grow out into the air, especially from the under surface, and form the whitish mould already described. The period from the time of infection to the production of a new crop of spores may be only a few hours, or at the most days, hence the rapidity with which the disease may spread. If dry

weather intervenes after a bad attack of Blight, the affected leaves shrivel and many of them subsequently fall off, leaving the haulm more or less bare.

Infection of the Tuber.—If the weather is wet after the foliage and haulm have been attacked, the tubers soon begin to be affected. Infection of the tubers is brought about by spores which, liberated from the surface of the leaves or stalks, are washed down into the soil. The first signs of disease in the tubers are discoloured, rusty patches just visible through the skin, but more evident when the skin is lightly scraped away. At first only a small part of the tuber may be attacked, but the disease may spread rapidly until half or more of the tuber is affected. Secondary changes frequently occur in blighted tubers owing to the activities of various micro-organisms which are not in themselves primary parasites, but which can destroy the tuber when once it has become killed by the blight fungus. A frequent result is that the tuber becomes reduced to an evil-smelling pulpy mass. In such cases, of course, it is often difficult or impossible to diagnose the original primary cause of the trouble, viz., Blight.

Source of New Infection each Season.—The re-appearance of Blight year after year is mainly due to the fact that each year a certain number of tubers infected with the disease are planted as seed. This in turn is due to the fact that slightly infected tubers are easily overlooked. Herein lies the advantage of boxing tubers, for if boxed the diseased tubers may very often be detected by the fact that they sprout prematurely, do not sprout at all or bear poor, weakly sprouts. Such tubers should not be planted. Under suitable weather conditions during the early part of the summer, some of the slightly diseased tubers, that escaped detection at the time of planting, may give rise to one or more diseased shoots which come above ground and on which spores develop, thus providing the starting point for an epidemic.

Infection also occasionally proceeds from plants derived from diseased tubers which have been left in the ground after digging, or from tubers which have lain about after the opening of clamps. No satisfactory evidence is yet forthcoming that the fungus persists during the winter in a dormant condition in the soil.

The Prevention of Blight by Spraying.—The object of spraying potatoes is to prevent infection and to limit the spread of Blight. In order to do this it is necessary to use a substance which, whilst not harmful to the potato plant, prevents the blight fungus from penetrating into the tissues

FIG. 1. Under surface of a potato leaf attacked by "blight."

FIG. 2. Upper surface of a potato leaf attacked by "blight."

of the leaves. The substance, if it is to be effective, must not only have this property but also must be capable of adhering firmly to the leaf.

A solution of copper sulphate, if used alone, though it would destroy the blight fungus, would also injure the foliage. When, however, copper sulphate is combined with lime or with washing soda, a fungicide is obtained which is both harmless to the potato foliage and destructive to the fungus. The use of Bordeaux mixture (copper sulphate combined with lime) and Burgundy mixture (copper sulphate combined with washing soda) has been common for many years for the purpose of preventing Blight in potatoes and it has been shown that the more effectively the foliage is covered with either of these mixtures, the more thoroughly are epidemics of Blight prevented.

By the use of Bordeaux or Burgundy mixtures, the spores of the fungus are prevented from producing threads which grow into the tissues of the leaf, and hence the haulm, instead of withering, as it does when attacked by Blight, remains healthy and green; the crop is therefore increased, and the tubers remain free from Blight.

In practice, however, no matter how carefully spraying may be done, it is not possible to cover the foliage so completely as to prevent all chance of infection. Nevertheless, spraying when well done, assists very materially in preventing the successive and rapid infections already described, and thus in limiting the extent of the disease both in the haulm and in the tubers.

It is important to understand that spraying is to be regarded as a means of prevention rather than as a cure; for when this is realized it becomes apparent firstly, that spraying must be done in good time, and secondly, that if heavy rains have washed the spraying material from the leaves, the operation must be repeated. In any case new foliage will have developed since the first application, and it is necessary to protect this as well as the old. This is the more important because in wet seasons the fungus finds conditions favourable for its rapid multiplication, so that if wet weather follows spraying it is doubly important to repeat the operation, and even to spray a third time. Some of the most successful large growers of potatoes no longer rely on spraying only once or twice, but make a practice of spraying as often as weather conditions make repetition necessary. The accumulated evidence of many years justifies the conclusion that the cost of spraying in an average season is amply repaid by the greater yield of healthy tubers.

Opinions differ as to the relative value of Bordeaux and Burgundy mixtures; there is, however, experimental evidence to show that they are equally efficient as fungicides. Where freshly-burnt stone-lime of good quality can be obtained the use of Bordeaux mixture is to be recommended; but if good lime is not readily obtainable, Burgundy mixture should be used.

Instructions for Making Burgundy Mixture.—The mixture should be made carefully, otherwise injury to the foliage may result. It is essential that all the soluble copper be precipitated by the addition of sufficient soda. Whilst adding the soda solution to the solution of copper sulphate the mixture must be vigorously stirred. The precipitate formed by the mingling of these two solutions should be flocculent and should remain in suspension for a considerable time.

The method of making Burgundy mixture is as follows:—

For Spraying One-third of an Acre (*say* 50 *rods*).

(1) Dissolve 4 lb. of sulphate of copper in five gallons of water in a barrel (iron, zinc, or galvanized vessels must not be used) capable of holding 40 gallons, then make up to 35 gallons.

(2) Dissolve in another vessel 5 lb. of washing soda (previously broken up into small pieces if necessary) in five gallons of water.

(3) When the soda has *completely* dissolved, pour (2) slowly into (1), stirring vigorously meanwhile.

N.B.—(Both copper sulphate and soda should be of fully 98 per cent. purity.)

Where smaller areas are to be sprayed, barrels capable of holding 10 gallons may be used; in that case, the quantities of copper sulphate and soda given above should be reduced to 1 lb. and 1¼ lb. respectively.

Burgundy mixture should be bright blue in colour, and should not settle for a considerable time. It should be used in a *fresh state* on the day on which it is prepared. Stale mixture is inefficient.

Both copper sulphate and washing soda dissolve somewhat slowly in cold water. The preparation of the solutions may be hastened by dissolving the copper sulphate and soda each in a gallon or so of hot water and making up the quantities indicated above by the addition of cold water; but before the solutions are mixed they must be allowed to become cold. In order to save time, the copper sulphate and soda solutions may be prepared one or more days beforehand, but they must not be mixed until just prior to use.

Sulphate of copper is *poisonous*, therefore the vessels in which the copper compounds have been prepared should not be used for the preparation of food.

The above formula gives what is known as 1 per cent. Burgundy mixture, *i.e.*, 1 per cent. of copper sulphate is used in its preparation. The use of Burgundy mixture of double this strength, *i.e.*, 2 per cent., is sometimes advocated, but results indicate that there is little to be gained by the application of the stronger fluid.

Instructions for Making Bordeaux Mixture.—This mixture should be made up in the following proportions:—

Copper Sulphate	4 lb.
*Quick Lime (freshly burnt lumps) ...	2 lb.
Water	40 gallons.

The copper sulphate should be dissolved in 35 gallons of water in a barrel. The lime should be placed in a separate vessel and slaked *slowly*. This is best done by adding only the amount of water which the lime can absorb. After the lime is thoroughly slaked, more water should be added gradually, stirring all the time, to make up to five gallons. It should then be strained through a fine sieve and added slowly to the solution of sulphate of copper, the contents of the barrel being vigorously stirred during the mixing. The above formula is for a 1 per cent. Bordeaux mixture, and to make the stronger, 2 per cent. solution, double the quantities of copper sulphate and lime are required for the same amount of water. There is, however, little to choose, as regards fungicidal power, between a 1 and a 2 per cent. mixture.

Prepared as described above and from pure materials, the mixtures will be correct and ready for immediate use. Copper sulphate solution is acid in character, and, if this acidity has not been completely neutralized by the soda or lime, scorching may occur. Although the amount of lime given in the above formula is ample for this purpose, it is nevertheless a wise precaution to dip a piece of blue litmus paper into the mixture before use. It should be submerged well below the surface and away from any froth which may have formed there, and it should remain blue. If it turns pink or red it will be necessary to add more soda or milk of lime. A clean, non-greasy, bright piece of

* Hydrate of lime is now prepared in a high degree of purity on a commercial scale and can be used for making Bordeaux mixture instead of quicklime. It is usually sent out in special paper-lined bags containing 56 lb. each, and if stored in a dry place will keep satisfactorily for two or three months. Three pounds of hydrate of lime are equivalent to two pounds of quicklime in making Bordeaux mixture.

steel or iron, such as the blade of an ordinary knife, or better still a clean, bright, wire nail may also be employed for testing. When held for a moment or two in the mixture and removed it should remain bright. If it shows a dark stain more soda or milk of lime is required.

Application of the Spraying Mixture.—For small areas Burgundy and Bordeaux mixtures are best applied by means of a knapsack machine, which must be provided with a nozzle that throws a fine misty spray. The person spraying should aim at covering the under surface as well as the upper surface of the leaves, as both sides are liable to infection. It is a mistake to apply too much fluid. On no account should the plants be "washed." All that is required is that, after spraying, the thinnest possible covering of the fungicide should lie evenly on the leaves and stalks; this is best attained by maintaining a high pressure in the spraying machine.

For the first spraying, about 120 gallons of the fungicide per acre, or $\frac{3}{4}$ gallon per rod, should be used, and for the second and subsequent sprayings, about 160 gallons per acre or one gallon per rod may be necessary in order to cover the foliage and the haulms thoroughly.

If a knapsack machine is not available, a syringe fitted with a nozzle which throws a mist-like spray may be used on small plots. Large fields of potatoes on the other hand should be sprayed by a horse-drawn machine. All spraying machines should be kept in good condition by oiling the important working parts frequently, and by careful washing out after use.

Dusting.—Another method of treatment is sometimes employed, viz., dry spraying or dusting the foliage of the plant with a prepared powder containing copper salts. To be effective the powder must be of satisfactory composition and it must be applied when the leaves are wet with dew or rain. Carefully conducted trials in Ireland and elsewhere have shown that dusting is not so effective as spraying in the ordinary way. On the other hand, where water is difficult to obtain, or where labour has to be economized, dry spraying is to be recommended rather than not spraying at all.

Dates for Spraying.—It is important to remember that the first spraying should be done before the disease appears, but in view of variations in the time of appearance of blight in different years and in different parts of the country, it is obvious that the dates for spraying must vary with the season and the district. Thus, potatoes in the south-western counties should, as a rule, be sprayed earlier than those in the east and north. The condition of the haulm must also be

FIG. 3.—Contrast between sprayed *(left)* and unsprayed *(right)* potato plants.

[*To face page* 10.

taken into account, it being difficult and sometimes impossible to spray effectively when the haulm is far advanced in growth. When possible, spraying should be done as soon as dry weather sets in after the first wet spell occurring at or about the dates given below. The best results are obtained when spraying is done during dry weather. It is better, however, to spray even when light rain is falling than to delay the operation too long in expectation of dry weather. Spraying should in no case be done in very wet weather, and if heavy rain falls before the mixture has dried on the foliage, thereby washing off much of it, a further application should be given as soon as conditions permit. Spraying should be carried out preferably in the early morning or evening, and not when a hot sun is shining.

In an average season an approximation to the following dates for the first spraying of second early and main crop potatoes will probably be satisfactory.

Cornwall	June 15th—end of June.
Devon	*N.B.*—Spraying should be done the last week of May for early varieties in the Penzance district and the first week of June in other forward districts of Cornwall, Devon, and the Isle of Wight.
Dorset	
Isle of Wight and Hampshire ...	
Somerset	
S.W. Wales	
Glamorganshire ...	July 1st—July 8th.
Gloucestershire ...	
Monmouthshire ...	
Sussex	
N.W. Wales ...	
Wiltshire	
Berkshire	July 8th—July 15th.
Herefordshire ...	
Kent	
Oxfordshire ...	
Surrey	
Worcestershire ...	
Remainder of the country	July 15th—July 31st.

(In the north-eastern counties spraying may usually be deferred until the last week of July.)

The second spraying should generally be done about three weeks after the first. It will serve to cover the new foliage and to protect more completely that already sprayed. In the south-west of England it will often be found advisable to spray a third time, and this applies also to other districts in wet seasons when heavy rains are frequent.

Even when Blight has broken out and the potatoes have not previously been sprayed, it is not too late to spray; for by so doing the rate of spread of the disease will be checked and the damage to the crop reduced, though the protection

from disease will usually be less complete than when spraying was done earlier.

There is some difference of opinion as to whether second earlies as well as main crop varieties should be sprayed. Where the disease is apt to appear early and to be especially virulent, as in the western half of the country, it is certainly advisable to spray second earlies, but where the foliage of these varieties is on the point of ripening before the disease appears, it is not worth while to spray them. Second earlies, which are planted late or which are to be lifted late, should, of course, be sprayed.

In the Penzance district it may also be necessary to spray first early varieties, as in adverse seasons serious outbreaks of disease are apt to occur even in first earlies. In other parts of the country the haulm of early varieties may be affected by Blight, but it is generally held not to be worth while to spray them, as the crop will usually be lifted before the disease affects the tubers. It should not be forfotten, however, that the disease on first earlies may spread from them to second earlies or main crop potatoes growing in their neighbourhood. First earlies, which have been planted late or which for any other reason are to remain in the ground some time after the appearance of disease, should be sprayed.

The Advantages and Disadvantages of Spraying.—The advantages derived from spraying have already been described. They are:—

(1) Prevention or delay of outbreak of the disease.
(2) Reduction of the virulence of the attack,

leading to

(3) An increased yield and a smaller amount of disease in the tubers.

As has already been stated, potato spraying has been practised for many years both in the British Isles and abroad, and the results of spraying show an overwhelming preponderance of evidence in favour of this operation. A striking example of protection from disease conferred by spraying is given in Fig. 3. In some cases, however, spraying has been found to be useless or actually harmful. Of these adverse results some have been due to inexperience in spraying. Sometimes the spraying material, instead of being used immediately whilst it was fresh, has been allowed to stand too long before use. In other cases the directions for making the spraying fluid have not been followed, and sometimes the spraying has not been done until the haulm has already made very considerable growth or until after disease has appeared, owing to the earliness of the season and to machines and chemicals being delivered late.

When, however, every allowance is made for these remediable defects in methods of spraying, the fact remains that in a certain number of cases competent observers have reached the conclusion that spraying has not been beneficial. It is, therefore, important to endeavour to ascertain what are the causes leading to the remarkable fact that, although in the majority of cases spraying has resulted in marked benefit to the crop, in some cases it has failed to produce this result.

Before considering this question it may be worth while to refer briefly to certain opinions adverse to spraying which are undoubtedly groundless.

Bees and Spraying.—It is claimed sometimes that spraying is poisonous to bees. There is no ground for this statement. Many varieties of potatoes fail to flower; others drop their flowers before the blossoms open. Among those that do flower, not a few varieties bear blossoms the stamens of which do not burst, and hence produce no free pollen which insects might gather in lieu of nectar. Neither do bees visit potato flowers in any considerable numbers, nor, if they did, would the small amount of fungicide deposited in the flower be likely to injure these insects.

Keeping-quality and Spraying.—Another baseless statement frequently made is that spraying spoils the keeping qualities of potatoes. The opposite is the truth, for, as already mentioned, the tubers of sprayed potatoes are less liable to disease than are those of unsprayed potatoes, and diseased tubers are apt to rot in store.

Cooking-quality and Spraying.—Again, it is sometimes asserted that sprayed potatoes turn black on cooking; but spraying has no influence on the colour which cooked potatoes assume. The blackening is a peculiarity due to the fact that certain varieties of potatoes sometimes contain a chemical substance which when exposed to the air is oxidised and gives rise to the discoloration.

Spraying and Seed Tubers.—Yet another objection is that seed taken from sprayed potatoes is unsatisfactory. Here also the objection has no basis in fact. Indeed, wherever disease has appeared, seed from sprayed potatoes is likely to be less diseased and hence to be better than seed from unsprayed potatoes. Moreover, it is a well-established fact that the best seed is obtained from somewhat immature tubers, and one of the effects of spraying is to prolong the growth of the haulm, and hence to delay the maturing of the crop.

Spraying and Risk of Poisoning Other Food Plants.—Another of these minor objections may be mentioned. It is often stated that when potatoes are inter-cropped there is a risk of food plants being poisoned. With ordinary inter-

crops of the cabbage tribe the danger is negligible; at the time of spraying the plants are not far advanced; the rains subsequent to spraying will gradually wash away any deposit which may be on the leaves, and the copper salt, if any, which remains will be confined to the outer leaves which are not used. At the same time it may be said that every precaution should be taken before these plants are prepared for food. If no copper salt is to be seen on them, no danger is to be feared. With food plants which are used in the raw state, however, as for example lettuce, there is an element of danger, and such crops should not be used for inter-cropping with potatoes.

Spraying and Ripening of the Crop.—Turning now to the more weighty objections which are raised, the first that deserves attention is the statement that the ripening of the crop is delayed owing to the haulm remaining green for a longer time. The statement is correct. The copper salt used in spraying exercises a preserving influence on the haulm, and in some seasons, with the latest ripening varieties, this might possibly be a disadvantage; on the other hand, in the majority of cases and seasons the extension of the growing period means an increase in the yield, and is therefore a decided advantage rather than a disadvantage.

Spraying and Injury to Foliage.—A certain number of complaints from inexperienced growers take the form that after spraying the lower yellow leaves fall off. This is no disadvantage; the yellowing leaves indicate by their colour that they are already moribund and their fall is no loss to the plant.

The most serious objection which has been brought against spraying is that it may lead to scorching and shedding of the leaves.

An examination of cases of this kind indicates that the scorching and other damage to the foliage, where it occurs, takes place under one or other of the following conditions:—

(1) In potatoes growing under bad conditions of cultivation, as, for example, in insufficiently drained, or in shallow, or light soils.

(2) Where mistakes are made in making up the mixture, particularly by using wrong proportions of the ingredients.

(3) In cases in which frost occurs after spraying has been done. It may be mentioned also, that in some places on the north-east coast, potatoes sprayed during the day may be "scorched" by the inopportune occurrence of a cold sea-fog the same night.

(4) Lack of success in spraying has also been traced to the fact that the sprayed plants have previously been attacked by insects. There is no doubt but that plants so attacked may suffer considerable damage from spraying, nor is this remarkable when it is remembered that aphides and similar insects make innumerable punctures in the leaves, through which the spraying material has ready means of access to the delicate internal tissues of the plant.

(5) Lastly, it appears to be an undoubted fact that potato crops grown in the neighbourhood of factories and in an atmosphere containing acid fumes may be affected adversely by spraying. The reason for this is not clear. It may be due to some chemical change brought about by the action of the acid fumes on the spray mixture. On the other hand it has been suggested that the potato foliage in many of these situations is more sensitive than that growing in purer air and hence is less able to resist the penetration into its tissues of the poisonous ingredients of the spray fluid.

Of the serious objections which have been raised, the first two are remediable: by ensuring better cultivation and by making up the spray fluid accurately, the damage may be prevented.

The third objection, damage by frost after spraying, can only be prevented by delaying spraying until risk of frost is over.

The last-mentioned cases of potatoes suffering from insect attack and of potatoes grown in fume-laden atmosphere are serious, and must be taken into consideration by those who are contemplating spraying.

In concluding this summary of objections, it is important to point out that the potato is subject to many diseases, of which Blight, although in many ways the most important, is only one; and it cannot be too strongly insisted upon that spraying is a preventive of Blight, and not of other potato diseases.

Other Means of Reducing the Damage Caused by Blight:—

(1) *Resistant Varieties.*—The most certain method of preventing Blight would be to cultivate varieties which resist its attack. In certain other diseases, as, for example, Wart Disease, immune varieties have been discovered, and are now in general use in infected areas. By planting these immune varieties the grower is able to secure a heavy crop and to be sure that it will not suffer from Wart Disease. It must, however, be clearly understood that a

variety which is immune from one disease, as, for example, Wart Disease, is not necessarily immune from another, and in point of fact the varieties immune from Wart Disease show all degrees of susceptibility to Blight. Unfortunately, the grower is not able at present to plant varieties absolutely immune from Blight, although a few are resistant. Of these, the President type (which includes Iron Duke and Scottish Farmer) is the best known. Irish Chieftain is also highly resistant to Blight. Little can be said about the relative susceptibility to Blight of the many varieties of potatoes grown on a large scale, because the degree of susceptibility depends largely upon the particular stock of the variety and upon the locality in which it is grown. In the absence, therefore, of varieties which are immune from or resistant to Blight, and at the same time are profitable commercially, the potato grower for the present must rely on other means of prevention.

(2) *Precautions at time of digging.*—It has already been explained that potato tubers become infected with Blight through the agency of spores produced on the haulms and foliage which fall to the ground below and are washed down through the soil into contact with the tubers. If potatoes are dug whilst the infected foliage is still partially green the tubers will be exposed to contact with such foliage and with the spores emanating from it, and they will therefore become infected. Moreover, the soil beneath foliage and haulms affected with Blight will be rich in fallen spores. Stirring such soil and the potato tubers lying in it is liable to increase the risk of infection of the tubers to a considerable degree. Hence potatoes should not be dug whilst the haulms are still blighted, otherwise tubers apparently healthy at digging time will show Blight later on in the pit or clamp. If for any reason the crop must be dug before the blighted haulms are completely dead, the haulms should be removed. The interval which should be allowed to elapse between the removal of such haulm and digging the crop should not be less than ten or twelve days; and the more extended it is, the less risk is there of tuber infection taking place. Partially living blighted haulms should never, under any circumstances, be used for covering a pit or clamp, even temporarily.

(3) *Earthing up.*—Tubers which are exposed to the air or those which are covered only by a thin layer of soil become infected with Blight from the spores which fall from the foliage much more readily than those which are more completely covered. Hence in cultural operations a good tilth is desirable and earthing up should be as thorough as possible.

WART DISEASE OF POTATOES.

Early History.—What is now generally known as the Wart Disease of potatoes was originally discovered in Upper Hungary (now part of Czecho-Slovakia) in 1896, and it was described briefly, but not very appropriately, as a new form of Scab. The view has been expressed that the disease was not only present in the British Isles at that time but had been here for ten, twenty or even more years previously; and there is some reason for believing that this may have been so. It may be, on the other hand, that the disease was introduced only a year or so after it was first encountered abroad. In any case the two earliest British records, made in 1898, show that the disease was already present here then, but those who saw it at that time did not diagnose it correctly. The first accurate account of Wart Disease published in this country, was based on experiments carried out by Professor Potter with material collected in Cheshire in 1900, and is to be found in the Board's (now the Ministry's) Journal for December, 1902. The serious nature of the disease and the damage that would result if it became widespread were then for the first time clearly pointed out. During the next few years many further cases came to light in England and Wales, and the presence of the disease was reported in Scotland in 1907 and in Ireland in 1908.

It would appear that Wart Disease was known by sight to growers before the attention of scientific men was directed to it, for it is almost certain that this was the disease that was known under such popular or local names as "Cauliflower Disease," "Black Scab," "Canker," "Fungus" and "Stag Head"—names that are now better forgotten. Even some of the scientific men who examined the disease in the early days did not at first understand it, and some amazing blunders were made, especially in regard to the identity of the organism that causes it. Gradually, however, its real nature and its prime significance to the potato-growing industry became only too clear, and it has long since gained world-wide notoriety. Following the passing of the Destructive Insects and Pests Act of 1907, Wart Disease was scheduled and made notifiable in 1908. Subsequently it has been the subject of special Orders under this Act, the last of which, promulgated in 1923, is still in force (see p. 45).

Geographical Distribution.—In England and Wales Wart Disease is most widely prevalent in the northern and midland counties, and for the purposes of the Wart Disease of Potatoes Order of 1923 above referred to, it has been found

necessary to certify as an "Infected Area"* the whole of Wales and Monmouth, the counties of Cheshire and Stafford, the whole of Lancashire south of the river Ribble, large areas in North Salop and Worcestershire and certain boroughs and parishes in adjacent counties. There are, in addition, a number of smaller "Infected Areas," notably in the industrial districts of Derby, Leicester and Nottingham. South of a line drawn from the Wash to the mouth of the Severn the intensity of the disease is very slight, and except in parts of Somerset and in the neighbourhood of London scattered outbreaks only have occurred. No case of Wart Disease has as yet been found in the county of Suffolk or in the Duchy of Cornwall.† In Scotland the disease is most prevalent in the midland and southern counties. In Northern Ireland it is found chiefly in County Down, whilst it also occurs in the neighbouring county of Louth in the Irish Free State.

Wart Disease has been found in some of the overseas parts of the Empire and in many foreign countries. In Europe for instance—apart from the first recorded outbreak in Hungary—it has been found at one time or another in Austria, Belgium, Czecho-Slovakia, Denmark, France, Germany, Holland, Norway, Poland, Sweden and Switzerland. Further afield it has been found in Malta, South Africa, Newfoundland, Canada and the United States of America. To many of these countries the disease has become distributed only within comparatively recent years, and it has not yet spread widely in them, whilst in some of them it may possibly be believed to have been suppressed. In others it has probably been present for a period as long as, or longer than, in the British Isles, and is now more or less widespread and thoroughly naturalised in them. It has not yet been reported from South America, the country of origin of the potato itself.

Losses due to Wart Disease.—It is impossible to estimate with accuracy our present actual losses from this disease. They must be on the whole relatively small, and are probably most marked in gardens and allotments where potatoes are grown on a comparatively small scale and with considerable frequency on the same plot of ground. Under such conditions the parasite establishes itself practically in perpetuity. But even under field conditions instances are not unknown where the planting of a susceptible variety in contaminated soil has resulted in practically a total loss of crop. Happily, owing to the discovery of immune

* This does not mean, of course, that the whole area, or that whole fields in it are necessarily badly infected, but that in the potato growing districts within it the number of recorded outbreaks is large, so that for administrative purposes the area has to be dealt with as a whole.

† A map of England and Wales, published in 1923, showing the principal Wart Disease Infected Areas can be obtained from the Ministry. Price 6d. post free.

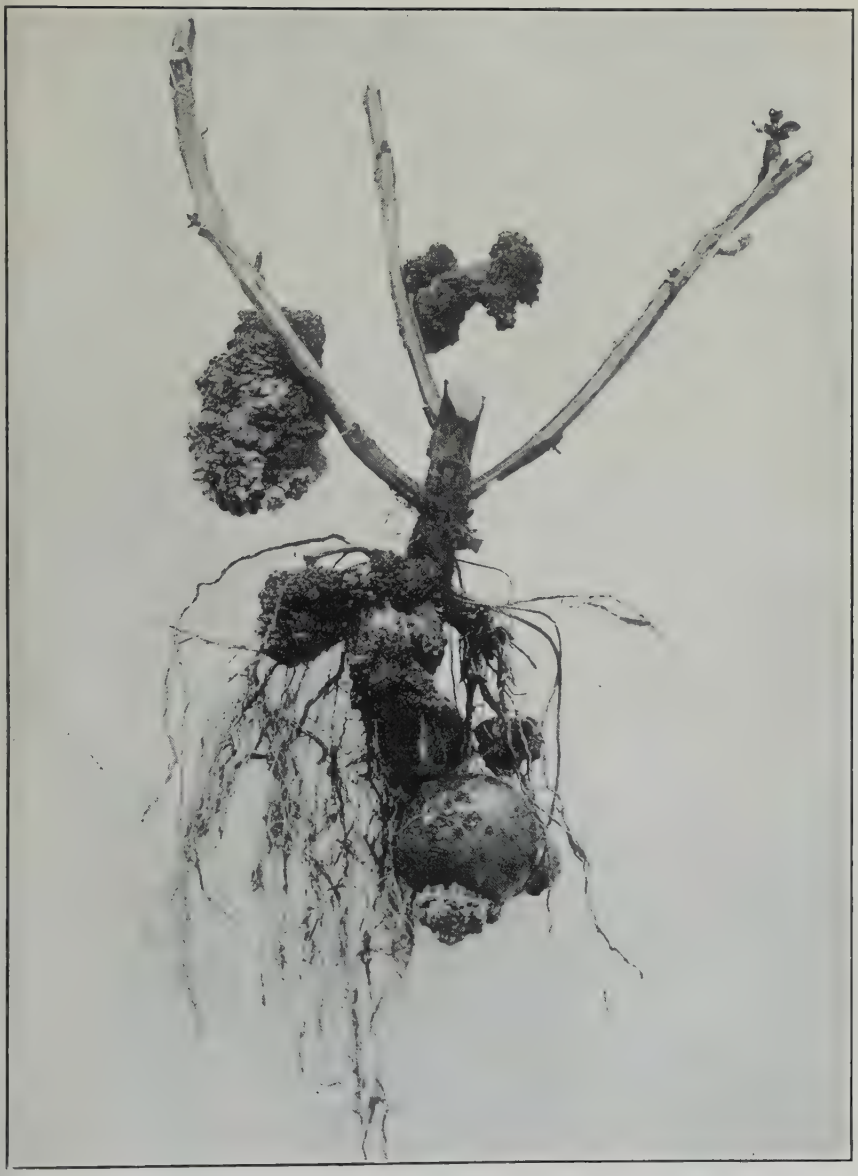


FIG. 1.—A potato plant, variety Cumberland Ideal, seriously attacked by Wart Disease. The main part of the haulm has been cut off. The warted growth on the left-hand branch just above soil level is an attacked aerial tuber; that still higher, on a branch in the centre is an attacked foliage leaf.

[*To face page* 38.

FIG. 2.—Potato tubers from a clamp opened in March showing the warts that had developed during storage.

varieties and to the measures of control which have now been in operation for many years, losses on a large scale are comparatively rare; but this should not lull growers into a sense of false security. The potential losses, *i.e.*, those that might occur, are enormous; Wart Disease is still a formidable menace, and no relaxation of effort to suppress it and prevent its further spread can be contemplated; for, as will be seen later, the possibility of infection from the soil remains latent for a long period of years.

Description of the Disease.—The parts of the plant particularly subject to attack are the tubers, but the stalks and even the foliage near ground level may occasionally become affected. The roots are, apparently, never attacked.* The general vigour of a potato plant affected with Wart Disease is not visibly reduced; indeed, it has been observed that such plants frequently grow bigger and bear larger and greener leaves than those that are free from the disease. Provided, of course, that it is not attacked by any other disease, such as Blight, the foliage may remain green longer than that of unaffected plants, and by this means diseased plants can sometimes be distinguished from healthy ones in the same field. The disease may sometimes be seen in the form of greenish-yellow, warty, or cauliflower-like growths at the surface of the soil near the bases of the haulms; but it is usually necessary to dig up the plant to disclose the true state of affairs. The general appearance of a badly attacked plant is illustrated in Fig. 1. It will be observed that the tubers are either converted more or less entirely into distorted, tuberculated masses, or bear warty out-growths. In time these softish masses and excrescences undergo a wet rot and turn black, leaving behind in the soil a quantity of highly infective material to attack succeeding potato crops. All the tubers on a diseased plant do not necessarily become affected, and on one and the same plant tubers in all stages of attack may often be seen.

The severity of attack and the degree of wartiness developed depend considerably upon the amount of moisture in the soil, being much less, as a rule, in dry seasons; and in such seasons there is a danger of the disease being overlooked. It also depends upon the variety of potato, some varieties being much more vigorously attacked than others, and some being actually immune (see p. 43). At the end of the season, when the crop is lifted, the warts may sometimes be extremely small, and they may be overlooked unless a

*Small galls or wart-like growths are formed on potato roots by the organism that causes Powdery Scab (Spongospora) (*see* Leaflet 232). They must not be mistaken for Wart Disease growths.

careful search is made. Indeed, a tuber may have become infected but warts, visible to the naked eye, may not have appeared at the time of lifting. The disease in such cases, however, usually progresses further in the pit or clamp; and, when opened later on, tubers with warted out-growths from their eyes, *i.e.*, malformed sprouts, will be discovered. (See Fig. 2.) Where infection is very slight, microscopical examination is the only sure means of detecting it.

Cause of the Disease.—Wart Disease is caused by the attacks of a minute parasitic organism belonging to a very lowly group of fungi.* Unlike the majority of fungi that cause diseases in plants this one possesses no mycelium (or spawn), and its life cycle is a comparatively simple one. From thick-walled, resistant, spore-cases (*sporangia*) in the soil minute, free-swimming, naked masses of protoplasm called *zoospores* are liberated, usually in early summer, each being provided with a single, long, thread-like swimming organ (*cilium*). A zoospore penetrates into the interior of a single cell on the surface of some young part of the potato plant (except the roots) and there proceeds to develop, producing in a short time a group of a few thin-walled spore sacs (*summer sporangia*) which ultimately become discharged to the exterior. They then burst, under moist conditions, and liberate fresh swarms of zoospores. As soon as the zoospore has entered the host cell, the neighbouring cells become stimulated to grow and multiply to an abnormal degree and in an anomalous manner; and it is the new growth thus arising that forms the tissue of the wart or of the tuberculated mass.

The zoospores liberated from the summer sporangia may cause fresh infections at once, and thus further batches of summer sporangia continue to be developed and the already formed warty growths become more extensive, while new ones may also be formed. Sometimes, however, the zoospores combine in pairs, and the entry of the product of this union into a host cell results in the development, not of a group of summer sporangia, but of a single, thick-walled, winter or resting sporangium which, by overgrowth of the surrounding cells subsequently becomes embedded somewhat below the surface of the warty tissue. When, usually towards the end of the season, the warts decay, these resting sporangia, which are present in them in large numbers, reach the soil; and it is by means of the zoospores liberated from them that fresh infections occur in succeeding seasons.

* When first discovered the fungus was named *Chrysophlyctis endobiotica*, but the present usually accepted name is *Synchytrium endobioticum*.

Some of the resting sporangia germinate in the year following their production, but many of them do not. For how many years such sporangia may remain alive in the soil is not known, but instances are known in which Wart Disease has appeared in a crop grown in land originally contaminated with sporangia, but in which no potatoes had been grown for periods of eight and twelve years. It is probable that the interval during which the possibility of infection remains may be considerably longer, and there is apparently at present no instance on record where soil, once well contaminated with the resting sporangia of the Wart Disease fungus, has ever yet become quite free from them and absolutely safe for the renewed planting in it of a susceptible variety.

Spread of the Disease.—Since the zoospores are capable of free movement in water and since they can also be carried by water currents they may be responsible for the spread of the disease, but probably to limited distances only, such as from one part of a plant to another part of the same plant or, at most, from one plant to its neighbour. By far the most important means of spreading the disease is by the distribution of the resting sporangia. These, as already explained, are developed in the warts and ultimately reach the soil. Hence anything which contains warty material or the remains of it may convey the germs of the disease with it when moved from place to place. Infected tubers, used for seed or otherwise, are obviously a very important means of distribution. Soil contaminated with resting sporangia may convey the disease when carried on the feet of man and domestic and other animals, including birds; or when adhering to tools and implements, cart wheels, or to the roots of plants such as cabbages, etc., that have been raised in contaminated soil. Dung from animals such as pigeons, geese and pigs fed with raw warty tubers, and manure containing diseased material from other sources have been shown to be a means of distribution, whilst washings from warty tubers thrown on to soil have been known to contaminate it. In short, in a hundred and one ways, material containing the resting sporangia may become accidentally dispersed from place to place, and the greatest possible care should be taken to prevent this by intelligent procedure where infected or contaminated material is known to exist.

Wart Disease on Hosts other than the Potato.—Under ordinary natural conditions the Wart Disease organism has not yet been found attacking any host plant, whether wild or cultivated, other than the potato. Under experimental conditions, however, such as by growing them in soil contaminated by the presence of the organism, plants of several species both wild

and cultivated have been found to be susceptible to infection. Thus, warty growths have been induced on the parts of the stem below ground and, to some extent, on the roots of tomatoes. Woody Nightshade (*Solanum Dulcamara*), Black Nightshade (*S. nigrum*) and Winged Nightshade (*S. alatum*) are also susceptible to slight attack on stem or roots or both, and the same applies to the roots of Henbane (*Hyoscyamus niger*). The so-called "Tea Plant" or "Chinese Box Thorn" (*Lycium barbarum* = *L. Chinense*), a straggling or climbing alien shrub with small lilac-coloured flowers often seen in cottage gardens, has also been recorded as susceptible. All of these plants belong to the same family as the potato, viz., the Solanaceae; others belonging to it have also been tested for susceptibility but have given negative results. In no case has infection been anything like so severe as it usually is in susceptible varieties of the potato; and these other hosts are, at present, probably of little importance in the maintenance or spread of the disease. Black Nightshade, an annual weed, is perhaps the only plant, of those mentioned, likely to occur in a potato plot or field, and that not so commonly as many other weeds. *Solanum alatum* is an annual, rather closely resembling Black Nightshade, but, although European is not a British plant.

It is of course possible that the Wart Disease organism may occur naturally on some species of plant which does not respond by the production of warty growths or of other evident symptoms of disease, so that its presence is not readily suspected. Such a species might be the original host-plant of the organism, from which the latter may have passed to the potato; but, if so, it has yet to be discovered. It is interesting to note, however, that the organism has been known to attack the stolons or underground tuber-bearing stems of the potato plant and to develop resting sporangia in them, without producing any visible signs of abnormal growth.

Varietal Susceptibility, Resistance and Immunity.—When the economic importance of Wart Disease became evident, field trials were at once instituted to ascertain whether all varieties were equally susceptible or not. It was soon found that some varieties became affected very readily and severely, others less so, while some were resistant. Most fortunately of all, it was found—as had indeed been anticipated would be the case from the results of previous inquiries carried on by the Ministry—that some varieties were actually immune; and this discovery has been of the utmost importance in connexion with the control of the disease. For several years these trials were continued by the Ministry and in 1920 they were transferred to the Potato Testing Station of the newly-founded National Institute of Agricultural Botany at Ormskirk where practically all of the commonly known varieties, as well as a large number of new varieties, have been and continue to be tested. As a result, well over two hundred distinct varieties have been found to be immune, whilst a somewhat larger number have proved to be more or less susceptible. Of this large number of immune varieties many possess no particular merit beyond that of immunity from Wart

Disease attack,* and they are therefore of little or no interest to the grower. Many of them, however, produce good crops of satisfactory quality, and are approved by the Ministry of Agriculture for planting on land on which Wart Disease has occurred. A full list of such approved immune varieties may be obtained, free of cost and post free, on application to the Ministry, but the following is a selection of some of the best immune varieties suitable for planting in contaminated land on most classes of soil:—

Early Varieties.—Di Vernon, Snowdrop (Witch Hill), Immune Ashleaf (Broadleaf), Boston Kidney (Dargill Early).
Second Early Varieties.—Arran Comrade, Great Scot, Ally.
Late Varieties.—Tinwald Perfection, Kerr's Pink, Majestic, Rhoderic Dhu.

Some of the better known varieties that are *not* immune from Wart Disease are:—*Arran Chief*, *Myatt's Ashleaf*, *British Queen*, *Eclipse* (*Sir J. Llewelyn*), *Duke of York*, *Epicure*, *Evergood*, *Field Marshal*, *King Edward*, *Ninety-fold*, *Royal Kidney* (*Queen Mary*), *Sharpe's Express and Up-to-Date.*

The question has been raised more than once as to whether immunity from Wart Disease is permanent in a given potato variety, or, in other words, whether immunity does not "break down." The answer is that no authentic case of loss of immunity has as yet been established in the field. Apparent cases of such loss have been due either to inadequacy of the test originally made or, more frequently, to the employment of stocks for trial that were not true to name or that contained rogues. The vital importance of the correct description and naming of potato varieties and of the avoidance of more than one name for one variety quickly became realized in connexion with Wart Disease immunity trials; and, following up the work of the previous four or five years done by a group of enthusiastic experts, a Potato Synonym Committee was established in 1920 by the National Institute of Agricultural Botany. The findings of this Committee are recognized by the Ministry, which now refuses to grant a certificate for any immune variety purporting to be new that the Committee declares to be merely an already existing and previously described sort.

It is true that a few varieties which, as the result of field tests, were at first considered to be immune, have had to be removed from that category and placed in the very

* It should be clearly understood that varieties immune from Wart Disease are not necessarily immune from or even resistant to any or all of the numerous other diseases that attack the potato.

highly resistant class. Delicate inoculation tests made in the laboratory, and microscopical control of the results such as cannot be carried out under field conditions, have shown that some six varieties, previously supposed to be immune, are, indeed, at least susceptible to infection. In no instance, however, are warts such as are characteristic of ordinary susceptible varieties produced; the development of the intruding parasite is extremely limited, and there is no production of resting sporangia. In the variety Great Scot it has been demonstrated that the parasite may actually enter the host, but it quickly succumbs to some reaction of the invaded cell, and no disease results.

Statements have been made that immune varieties lose that character if they become attacked by one or other of the so-called Virus Diseases (Leaf-Roll, Mosaic, etc.), but experiments have proved that this is not the case.

What precisely it is that renders certain varieties immune from the disease is not known; but whatever the factor may be, it seems to be bound up intimately with the protoplasm of the living host cell itself. Infection experiments have shown that portions of a susceptible variety growing, after grafting, upon an immune variety do not acquire immunity from anything that may pass from the latter to the former; nor do portions of an immune variety, when grafted upon a susceptible one thereby lose their property of immunity.

Eradication of Wart Disease.—Since Wart Disease is contracted from an organism present in the soil, the idea of soil sterilization or disinfection as a possible means of eradication at once presents itself. Unfortunately this is a most difficult problem; and, although numerous experiments have been made both in this country and abroad, no really practicable method of soil treatment has yet been evolved. The organism could of course be starved out, by refraining from growing susceptible plants in contaminated soil for the necessary length of time; but what this length of time may be is not known, although it certainly must be a very considerable period of years. Where such a course is possible, the safest plan to pursue with contaminated land would be to put it out of cultivation altogether by, say, laying it down to grass. By this means the parasite would be deprived of its host and would slowly dwindle away, while the risk of its distribution through movement of the soil would be reduced to a minimum. Warty material is best disposed of by burning, where this is possible. It should never be used for feeding purposes unless previously very thoroughly boiled.

Control of the Disease.—The essence of control of the disease lies in preventing—

(*a*) the production of further infective material—by stopping the planting of a susceptible host in already contaminated soil, and

(*b*) the creation of new centres of disease—by avoiding the distribution of existing infective material.

In England and Wales this is effected through the operation of the

WART DISEASE OF POTATOES ORDER OF 1923

issued under the Destructive Insects and Pests Acts, 1877 to 1927. The main requirements of the Order include the following:—

(1) Any occupier of land on which Wart Disease exists or appears to exist must at once report the occurrence to the Ministry or to an Inspector of the Ministry. This must be done even if the disease on the land has been reported in a previous year.

(2) Potatoes visibly affected with Wart Disease may not be sold or offered for sale.

(3) No potatoes, wherever grown and whether considered healthy or not, may be planted or sold for planting in England and Wales unless they have been officially certified as having been either (*a*) grown on land believed to be free from Wart Disease, or (*b*) inspected and that Wart Disease was not found to exist, or (*c*) inspected whilst growing and found to be of an approved immune variety true to type. The only exception to this is that a grower does not require a certificate to plant seed potatoes saved from his previous year's crop grown on the same land.

(4) On land on which Wart Disease has occurred at any time, only those stocks of approved immune varieties that have been officially certified as true to type and reasonably free from rogues may be planted; but a grower may plant seed of approved immune varieties saved from his previous year's crop grown on the same land.

(5) No potatoes grown in an Infected Area may be planted or sold for planting in land not in an Infected Area. The only potatoes that may be sent out of an Infected Area into other districts are potatoes of approved immune varieties for "ware" purposes, and these must be accompanied by a statement that they are of an approved immune variety, that they were grown in an Infected Area, and that they are not intended for planting.

(6) Potatoes grown in Scotland or Ireland, whether for seed or for consumption, may be sold in England and Wales only subject to certain restrictions also laid down in the Order; whilst potatoes grown outside the British Isles may be planted only by special licence of the Ministry.

Any contravention of the terms of the Order renders the person offending liable on conviction, to a penalty of Ten Pounds for the first offence, and of Fifty Pounds in respect of a second or subsequent offence.

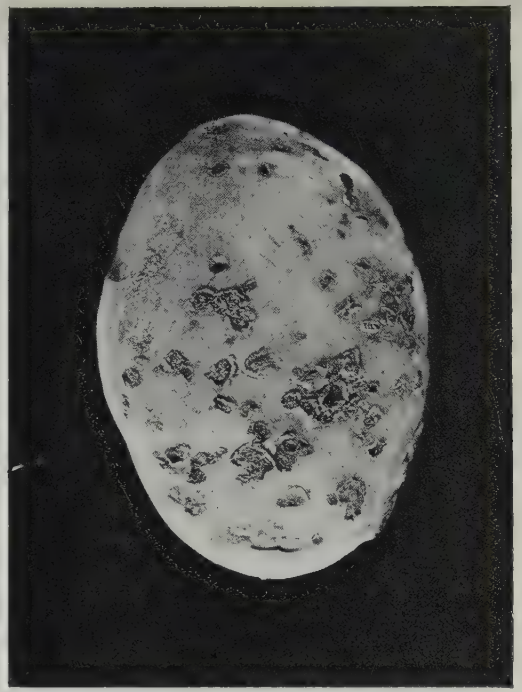
POWDERY SCAB OF POTATOES.

Of the various forms of scab found on potato tubers the disease termed Powdery (or Corky Scab), though not so readily diagnosed with certainty, perhaps, as some others, is very widely distributed, and is liable, under certain conditions, to bring about serious injury. In its mild form Powdery Scab usually appears as small, roundish or irregular, rough scabs on the skin of the tuber, which are comparatively harmless. In other cases the damage occasioned is more severe, and considerable destruction of the flesh is produced.

Powdery Scab is due to an exceedingly minute parasitic organism known as *Spongospora subterranea*. This parasite, as its specific name implies, lives underground, and belongs to the same group of organisms—the slime fungi—as does the parasite causing Finger and Toe or Club-root in cabbage and other cruciferous plants. *Spongospora* has been known in Britain for many years; it also occurs in various other countries in northern and central Europe, and is known in Canada and the United States. Quite recently it has been discovered on wild potatoes in remote and isolated districts of Peru, so that it is highly probable that its native home is in South America, and that it was many years ago introduced with potato tubers.

In the British Isles, Powdery Scab is perhaps most prevalent in the wetter parts of the country. It is widely distributed in Scotland where it is sometimes destructive, and the same applies to Wales and certain counties in the northern part of England. In Ireland also it is frequent, but in its severe form it occurs as a rule only in the ill-drained boggy districts of the Western counties. In the remaining parts of the British Isles Powdery Scab seldom causes trouble, and it would appear that in such localities the soil and climate are not favourable to the extensive development of the parasite, and that consequently there is little cause for anxiety as to its future increase.

Fig. 1.—Early stages of Powdery Scab, showing wart-like swellings from which the spore-balls have not yet been discharged.



Powdery Scab.

Fig. 2.—Later stage showing open scabs after liberation of most of the spore-balls.

[*To face page* 46.

POWDERY OR CORKY SCAB.

FIG. 3.—Canker form of the disease, showing the destruction of the flesh of the tuber.

FIG. 4.—Tuber of abnormal shape attacked in several places by Powdery Scab, and showing large open scabs.

Description of the Disease.—In its earliest stages the disease appears in the form of small conical or rounded elevations on the surface of the young potato tubers, or sometimes as distinct pimples or small wart-like swellings (Fig. 1). These warts are at first covered with the unbroken skin of the tuber, and are, when freshly removed from the soil, pale in colour, though they soon become brown. Within the cells of the swellings is to be found the parasite, and it is owing to the irritation of the tuber by the parasite that they are produced. With the growth of *Spongospora* and the continued irritation, the swellings enlarge and soon rupture the covering skin. The parasite has at this stage reached its reproductive phase and produced innumerable minute brown bodies known as spore-balls. They receive this name from the fact that each consists of a collection of spores held together in a more or less sponge-like spherical or oval mass. The cells of the potato tuber in which the spore-balls are contained die, and on their decay the latter are set free, and are visible with a lens as a brown powder. Many of the spore-balls are liberated before the tubers are lifted, and this brings about contamination of the soil. When the spore-balls have disappeared from the surface of the tuber a small circular open scab (Fig. 2) is left which, with the naked eye alone, is often indistinguishable from a spot of ordinary brown scab.

The presence of a few small scabs such as those described above does not seriously injure the tubers, but occasionally they occur so numerously that the market value is depreciated.

When Powdery Scab assumes its severe form, actual destruction of the flesh of the tuber takes place, the ultimate appearance presented being of the nature of a canker. Such injury is shown in Fig. 3, where the flesh is seen to have been destroyed, a large mass of spore-balls which was at first covered by the skin of the tuber, having now fallen away. Between this canker form and the small scabs described above, all transitions occur. In yet other cases scabs are found in protuberances or abnormal outgrowths on the tuber (Fig. 4). It is not certain whether the protuberances themselves are produced entirely by the parasite or whether they are not merely secondary or late outgrowths which, owing to their tender skin, are more susceptible to attack than the older parts of the tuber. The specimens of these two forms of injury figured (Fig. 3 and 4) are quite typical, and clearly indicate the nature of the destruction, but in bad cases the damage is still more extensive.

The production of the canker-form of Powdery Scab is generally due to the presence of a wet, poorly-drained soil.

That this is the case is shown not only by its distribution, but by direct experiments, which have been conducted both in the open and under glass. The disease is moreover less prevalent in dry seasons, and there can be no doubt that abundant moisture in the soil is one of the most favourable factors for its development. The presence of an excess of lime also tends to increase and intensify the disease.

In addition to attacking the tubers *Spongospora* infects the roots of the potato plant and forms on them small whitish galls about the size of a pea, somewhat similar in appearance to the bacterial nodules present on the roots of plants of the pea and bean family. These galls are sometimes present in considerable numbers, but apparently they do not exercise any injurious influence on the growth of the plants. Spore-balls are formed in the root galls as on the tubers, and on the decay of the galls they are liberated in the soil. This takes place rather early, and consequently the root-galls are not often observed, as, by lifting time, they have mostly disappeared.

Powdery Scab is essentially a disease of the potato, no other field-crop being subject to it. Until recently *Spongospora* was thought to be confined to this plant, but experiments have shown that it is capable of infecting certain wild American species of *Solanum*, and also the tomato. On all of these plants the parasite forms small root-galls. These, as in the potato, do not injuriously affect the root system, but in the tomato it should be remembered that this plant may possibly act as a host for *Spongospora* when potato plants are absent and thus keep up the contamination of the soil.

As will be gathered from the above description the injury produced by Powdery Scab is as a rule not great. In mild cases it consists merely in surface scabbing. This, while it causes disfigurement, and depreciation of the market value, is not in itself serious, nor does it materially injure the crop. In the case, however, of a severe attack much of the crop may be lost.

Source of Infection and Spread of Powdery Scab.—When the spore-balls are liberated and pass into the soil from a diseased crop the soil becomes contaminated, and a fresh outbreak of disease may arise in the following or subsequent years. The spore-balls remain dormant for a time, probably throughout the whole winter, but under suitable conditions of warmth and moisture they germinate, each component spore of the spore-balls giving rise to very minute motile spores or "zoospores." Countless thousands of zoospores might, therefore, be produced from a single badly infected potato plant. The zoospores move about in the moist soil, and coming in contact with the young tubers

of the new crop infect them; and by irritation and stimulation of the tissues cause the cells to divide and thus form the small warts or pimples referred to above.

The spread of the disease from one area to another is due mainly to the distribution and planting of affected tubers. The spore-balls present on such tubers germinate in the soil and infect the new crop. Sound tubers which have been grown in contaminated soil and sound tubers which have been in contact with diseased ones may, through the spore-balls which adhere to their skin, be contaminated, and thus spread the disease. Further, Powdery Scab may be distributed by means of contaminated manure and inadvertently by human agency such as the use of contaminated implements, sacks, or utensils, as well as by soil conveyed on the boots and clothes of workers.

The exact length of time the spore-balls retain their vitality is not known. But it has been proved beyond question that when once a soil has been contaminated it will retain its power of infecting a new crop for three years. There is also evidence for believing that the soil remains contaminated for at least five years and possibly longer; consequently a very long rotation must be given if it is desired to stamp out the disease in the soil.

Investigations on Disinfection of Soil and Seed.—Two of the most obvious methods of control consist in the treatment of contaminated soil and the disinfection of infected tubers. In both these directions investigations have been carried out in Ireland, and it may be useful to mention those substances which have already been experimented with and to indicate the nature of the results obtained.*

Seed Treatment.—With regard to seed, the most suitable methods of disinfection were found to consist in either (*a*) steeping the infected tubers in a dilute solution of formalin, or (*b*) rolling them when moist in flowers of sulphur. Provided the ground is free from contamination, slightly infected tubers if treated in this way will give, even in the west of Ireland where the climate is highly favourable to Powdery Scab, practically a clean crop. Steeping in a solution of copper sulphate, or treatment with Burgundy Mixture, though successful for disinfection seriously reduces the yield and cannot therefore be recommended.

Soil Treatment.—The disinfection of the soil is a very much more difficult matter. Dressing contaminated soil with lime only increases the disease, and an excess of lime

* The details of these experiments will be found in the *Journal* of the Department of Agriculture and Technical Instruction for Ireland, Vols. X.-XVI.

in any soil favours the activity of the parasite. Acid (or acid-forming) substances have been tested, and of these a liberal dressing with flowers of sulphur was found to give the best result, though from a practical standpoint the results were not so good as might be wished. Sulphate of potash proved beneficial, as did also a mixture of ammonium sulphate and lime applied a fortnight before planting, but neither of them sufficiently so to be worth recommending. Superphosphate of lime in excess reduces the disease, but is apt to have an adverse effect upon the yield, and the same may be said, but to a much greater degree, of copper sulphate and formalin. Other substances which have been tried but without success are:—carbolineum, carbolic acid, petrol, chloride of lime, calcium cyanamide, gas-lime, muriate of potash and sawdust.

Distinctions from other Diseases.—Mild forms of Powdery Scab closely resemble the Common Brown Scab (*see* page 61), and in the past have probably often been mistaken for it. In Powdery Scab, however, the scabs are more regular and uniform in shape, and they frequently possess around their margins the remains of the broken skin of the tuber (Fig. 2). Unless very old they contain the remains of the brown powdery mass of spore-balls. In this disease there is, moreover, below the scab a definite brownish layer of cork. In ordinary scab there are no spore-balls and only an exceedingly thin layer of separating corky cells. Microscopical examination is, however, often necessary, and when this is resorted to the very curiously formed spore-balls of Powdery Scab are so characteristic that the disease can be recognized immediately.

Bad cases of Powdery Scab are on the other hand liable to be confused with the much more serious Wart Disease, especially when they have become old and decayed. Here again microscopical examination is often necessary. Doubtful specimens should, therefore, be submitted to a competent mycologist for identification. Wart Disease is fully dealt with on page 37.

Methods of Control. — 1. *Seed Treatment.* — Potatoes materially affected with scab of any kind should preferably not be used for seed. This is particularly important in the case of clean land. Seed infected with Powdery Scab, and seed which, though sound, has been contaminated by contact with diseased tubers or contaminated soil, may be disinfected by steeping for three hours in a weak solution of commercial formalin (½ pint of formalin to 15 gallons of water).

2. *Soil Treatment*.—Potatoes should not be grown on badly contaminated land, but if this is inevitable, a dressing of flowers of sulphur at the rate of 6½ cwt. per acre (2½ oz. per sq. yard) will reduce the disease and probably also increase the yield. Lime should not be used, but any improvement in the drainage of the land would be beneficial.

3. *Prevention of Spread.*—All general sanitary precautions should be taken. Contaminated bags and other articles must not be used for clean seed, and care should be taken not to spread the disease by the use of contaminated manure or carts and implements. Badly infected tubers or parings should be boiled and fed to pigs. The sale or exposure for sale for planting of tubers substantially attacked by Powdery Scab is prohibited under the Sale of Diseased Plants Order of 1927.

4. *Rotation of Crop.*—As no other field crop is affected by Powdery Scab a long rotation will help to starve out the parasite from the soil.

5. *Resistant Varieties.*—Varieties of potatoes (if any) which appear to be locally less attacked by the disease should be selected for cultivation. No varieties which are altogether immune from Powdery Scab have so far been discovered.

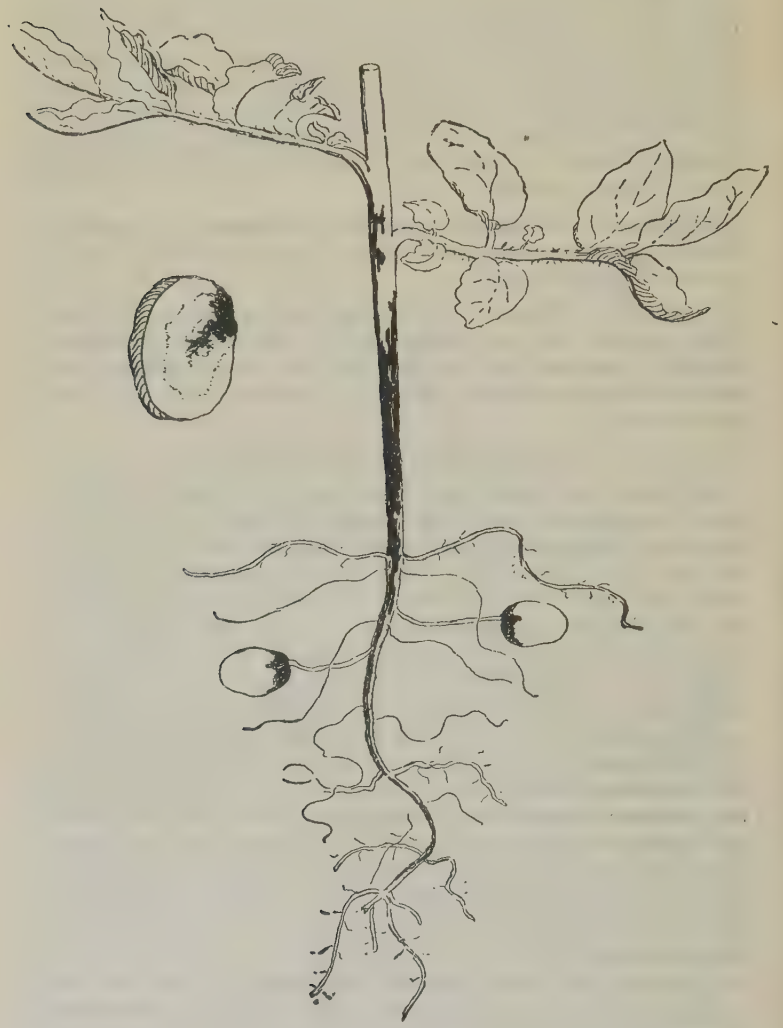
BLACK-LEG OF POTATOES.

Although not so widely recognized as it might be Black-leg of potatoes is a common disease in Britain. It is well known on the continent of Europe, where it was first studied in detail, and it is to be found in practically every country where the potato is cultivated. The losses caused by Black-leg are often not regarded as serious since the disease is not epidemic in character as is the ordinary potato Blight (*see* page 25). Nevertheless, the losses in the aggregate reach in an average season a considerable amount, and in unfavourable and wet seasons they may be really severe.

The disease is of a bacterial nature; and although the causative organisms found in the various countries in which the disease has been investigated, show certain slight differences and have received different names, yet recent researches tend to show that most of them are, if not actually identical, very closely related. For practical purposes the disease may be regarded as being caused by a single species, that known as *Bacillus phytophthorus*.

Symptoms of the Disease.—Black-leg is one of the earliest potato diseases to show itself. Affected plants may be seen as early as the middle of June, but they may continue to make their appearance till considerably later.

Diseased plants are somewhat stunted and are conspicuous even at a distance by their pale green or yellow foliage. The upper leaves show a tendency to remain small, stiff and erect, whilst the margins of the leaflets are generally rolled inwards.



Black-Leg of Potatoes.—Attacked stem and diseased tubers.

The most characteristic feature is to be found at the base of the stem. If affected stalks are pulled up they will come away easily and be found to be rotten and black at their bases (*see* illustration). In some plants all the stalks will be affected in this way, in others only one or two. The outer or cortical tissues will be soft and decayed, or perhaps entirely rotted away, and the pith will be found to be blackened or destroyed. In some cases the destruction of the pith extends upwards for a considerable distance. The old set or seed potato will be completely rotted away.

Another indication of Black-leg is seen when affected stems are cut transversely. The section will show near its outer part three brown spots which are the woody portions of the principal vascular bundles. The brown colour is due to the action of the bacteria, and in bad cases it extends to the extreme apex of the shoot and sometimes manifests itself externally in the form of black streaks on the stem. It will be noted also that affected stems are tougher than those which are healthy. These two features—the discoloured bundles and the tough stems—are not, however, confined to Black-leg, but occur also in certain wilt diseases.

Later Stages and Infection of the Tubers.—As the season advances the leaves of affected plants turn brown and the stalks usually die off. If the disease develops early this will take place before any new tubers are produced, but where the disease may have progressed more slowly or commenced later new tubers will have been formed, and a certain number of these will be affected, the bacteria having passed along the rhizomes (or underground stems) and entered in at the heel-end.

Diseased tubers may be recognized by being soft and discoloured, especially at the heel-end, and by the flesh being brown and ultimately becoming wet and rotten. In bad attacks practically all the tubers decay in the ground; but in many cases the disease does not advance so rapidly, and the tubers remain sound for a time but decay badly in storage. Those tubers which are only slightly affected survive the winter and if planted give rise to diseased plants.

Decay in the store is also increased by the infection of healthy tubers through contact with those which are diseased. The soft, wet mass formed by the rotting diseased tubers contains millions of the parasitic bacteria, and it has been proved by experiment that water containing these bacteria is capable of infecting and causing the decay of sound tubers. The parasite in this case enters through the skin by way of the lenticels (or breathing pores) and probably also by means of wounds. The heavy losses which

occasionally occur in potato pits are largely attributable to this form of infection.

Spread of the Disease.—It has been proved beyond all question that Black-leg is propagated by the use of diseased "seed." The seed may sometimes be so slightly infected as to appear quite sound externally, yet if planted it may produce diseased plants. The greatest care, therefore, should be exercised that none of the progeny of diseased plants be saved for planting purposes. It should be remembered that tuber-infection is liable to take place, not only when plants are so badly attacked that they die, but when only one or two shoots are affected and the plants as a whole continue to live.

Doubtless the disease may occasionally be contracted directly from contaminated soil; but in this country attempts to effect this have succeeded only when such soil has deliberately been heavily dosed with the bacillus and also kept in a practically water-logged condition. Under normal conditions, therefore, spread of the disease through infection from the soil is of no serious import. The disease does not spread from plant to plant in the field and therefore does not become epidemic.

Measures of Control.—1. *Use of sound seed.*—It is of the utmost importance to use only sound seed. Tubers which are the produce of affected plants, however sound they may appear to be, should never be saved for seed purposes.

2. *Destruction of Diseased Plants.*—As far as is practicable all diseased plants should be dug up and destroyed as soon as noticed, and the young tubers removed from the soil. Tubers which are sound may be used for immediate consumption. The remainder should be destroyed.

3. *Inspection of Seed Crop.*—Black-leg is widely distributed in some of the "seed" growing districts. When potatoes are specially grown for seed purposes it is most important to inspect the crop during the growing season, from June to August, with the special object of removing affected plants. It is only by this means that a clean sample of seed can be hoped for.

4. *Storage.*—Care should be exercised in constructing the pits. All tubers showing any trace of disease should be excluded, and the pits made as dry and as well ventilated as possible.

POTATO LEAF-ROLL.

Although the potato was introduced into Britain during the latter half of the sixteenth century, it was not widely cultivated until some time after the middle of the eighteenth. Not long after this, and for a period which extended for a decade or so into the nineteenth century,

there were many complaints by growers of serious losses in the crop owing to a disorder which was called "The Curl." Much was written and many and diverse views were held as to the nature and cause of The Curl, and suggestions for obviating it were not wanting. Nevertheless its true nature remained uncertain. After about the year 1812 the importance of The Curl appears to have declined; and, before the middle of the nineteenth century, a new potato scourge which completely overshadowed The Curl made its appearance, namely, "Blight."

At about the beginning of the present century there arose, particularly on the Continent of Europe and, later on, in Britain and elsewhere, renewed complaints of a disease in potatoes of somewhat the same general type as that formerly known as The Curl. This disease, like The Curl, was characterized by stunted growth and curling or rolling of the foliage, accompanied by more or less serious diminution in yield and general deterioration, degeneration or "running out" of stocks. This was called the Leaf-Roll disease. At first it was thought to be due to a parasitic fungus, but, later on, this view was abandoned.

Largely in consequence of the alarm raised, potato diseases have been studied more intensively since that time; and one result has been to show that The Curl was not a single specific disease, but consisted of several distinct maladies, some of them more or less closely akin to one another, but others clearly different in nature. Leaf-Roll is one of these diseases; and the name Curl is still occasionally applied to it, but only in this country. Owing to the lack of preciseness with which the term Curl has been used in the past, however, it is not desirable to retain this name for any one of the specific diseases which were formerly included under it.

Distribution of Leaf-Roll.—Leaf-Roll has a world-wide distribution, and is probably to be found to some extent wherever potatoes are cultivated. In Britain it is very prevalent on the lighter soils of the southern and drier parts of the country, and its ravages are apt to be particularly severe in those districts when locally-grown seed is planted. It is, however, by no means confined to such localities, and in recent years it has become increasingly obvious further north. Even in Scotland it is far from being a negligible factor—perhaps, indeed, it is one of the most important factors—in the successful production of potatoes, especially those destined for seed.

Susceptibility of Varieties.—Although nearly all varieties are liable to Leaf-Roll, some appear to be more subject to it than others. It is particularly common and severe in

such first earlies as Duke of York (Midlothian Early) and May Queen. Sharpe's Express also suffers, but not so seriously. Of second earlies, British Queen is liable to severe attack, and of main crop varieties Up-to-Date and King Edward. President (including Scottish Farmer and Iron Duke) is also particularly susceptible.

Of first early varieties which appear to be somewhat resistant or tolerant, Epicure, Eclipse and Ninety-Fold usually suffer less than those named above, whilst Resistant Snowdrop (Witch-Hill), a variety immune from Wart Disease, appears to be very highly resistant to Leaf-Roll. Of later varieties, Arran Chief, The Ally, Templar and especially Great Scot are seldom seriously attacked.

Losses due to Leaf-Roll.—The general effect of Leaf-Roll is shown by a serious reduction in yield, the average size and number of tubers produced being usually much diminished. Moreover, this effect is passed on to succeeding generations through the tubers produced by diseased plants. It will therefore readily be understood why Leaf-Roll is classed amongst those diseases of the " degeneration " or " running out " type.

A clear idea of the losses which may be caused by Leaf-Roll can be gained from the results of a series of experiments carried out by the Ministry in 1921. Healthy seed potatoes and others derived from a crop suffering from Leaf-Roll were grown side by side, under identical conditions, in ten different localities in England and Wales. The diminution in yield on the Leaf-Roll plots varied from 21 to 63 per cent., and the average loss was nearly 51 per cent. Other experiments, carried out in the two following years, showed losses of over 45 and over 52 per cent. respectively. Such extensive losses are to be regarded as quite normal in crops derived from tubers the whole of which are infected with the disease. Where partly healthy and partly diseased seed is employed the immediate losses are naturally not so great; but since the effects of the disease increase, owing to its being perpetuated through the seed, the ultimate losses are bound to be very great.

Symptoms of the Disease.—Plants which have only quite recently become infected may show no signs whatever of such infection; and this may be the case throughout the remainder of the season. That such plants really carry the disease, however, will be evident in the following season when the symptoms of Leaf-Roll will appear in their progeny. It is perhaps only when healthy plants become infected comparatively early in the season that unquestionable symptoms of Leaf-Roll appear in that season. Such

symptoms will then be shown primarily, if not exclusively, in the new parts which have developed since infection took place, that is in the upper parts of the plant.

The characteristic symptoms of the disease are most marked in plants produced by the tubers of diseased plants of the previous year. In such plants the lower leaves, especially, exhibit at a comparatively early stage a rolling upwards and inwards of the margins of their leaflets, the rolling being at first more pronounced at the bases of the leaflets than at their tips. (See illustration.) This rolling may spread to the leaflets of the upper and younger leaves as the plant develops, so that the whole foliage eventually may have a "rolled" appearance. Sometimes, however, this rolling of the upper leaflets does not occur or is not strongly marked, and the importance for diagnostic purposes of the rolling of the leaflets of the lower, first developed leaves is very great. It assists, for instance, in distinguishing Leaf-Roll from Verticillium Wilt, Black Leg and other diseases.

The leaflets are often thicker, more crisp and drier than normal; and when knocked together they make a rattling sound. The midribs of the leaves frequently point upwards at a somewhat acute angle, and this gives the whole plant a somewhat stiff, gaunt and V-like appearance. The whole plant may also be much reduced in size, and in severe cases it is often quite dwarfed and reduced to a single small stalk.

Associated with the rolling of the foliage colour changes often occur, especially in particular varieties. Thus, in President, in Crusader, and to some extent in Kerr's Pink, a reddish colour occurs. Seen from a distance plants affected with Leaf-Roll often appear pale because the lighter, under-surfaces of the leaflets are exposed to view instead of the darker upper-surfaces. Dark brown or black areas of dead tissue are sometimes prevalent on the leaves of plants affected with Leaf-Roll, but they are not necessarily characteristic of this disease.*

The tubers produced by plants affected with Leaf-Roll are fewer in number and smaller in size, on the whole, than those produced by healthy plants. The old set or seed usually remains in the soil undecayed; but this is by no means an infallible sign of the disease. No certain means have as yet been found for detecting the presence of the disease in the tubers, and diseased tubers cannot be distinguished from healthy ones except by growing plants from them.

*Sometimes a potato plant affected with Leaf-Roll may suffer simultaneously from one or more other diseases. In such circumstances diagnosis is often extremely difficult.

As regards internal symptoms of the disease it is found that the rolled leaflets contain an excess of starch. It has been suggested, in fact, that the mechanical rolling of the leaflets is more or less directly caused by the great accumulation of starch grains in their cells. In healthy leaves the starch manufactured in daylight becomes converted into sugar during the hours of darkness, and possibly also to some extent at other times. This sugar is carried away through the conducting tissues in the leaf-stalk and stem, and reaches, on the one hand, the newly developing tubers, where it is converted back to starch and deposited as reserve food, or, on the other, the growing points of roots and shoots, where it is available for the development of new growth.

In the leaves of plants affected with Leaf-Roll, however, this normal process of food manufacture, followed or accompanied by translocation, is upset. Heavy congestion of starch occurs in such leaves; and, even after prolonged darkening, it is found that this starch has not become translocated. Further, certain parts of the food-conducting tissues of the leaves and stems of plants suffering from Leaf-Roll sooner or later become disorganized and incapable of functioning normally. It is this combination of starch congestion in the foliage with failure in the channels of transport which prevents the green leaf from continuing to manufacture the food necessary for further growth or required for storage purposes. This appears to be the fundamental reason why plants affected with Leaf-Roll are limited both in growth and productivity.

Cause and Transmission of Leaf-Roll.—Perhaps the most important discovery made in recent years concerning Leaf-Roll (and also concerning Mosaic and some other degeneration diseases) is that it is a *transmissible disease*, and that it can be transferred readily from a diseased to a healthy plant. Such transmission can be carried out artificially by grafting either a scion or a portion of a tuber from a diseased plant on a healthy stalk or portion of tuber respectively. But transmission occurs more readily still by means of sucking insects, such as aphides (green fly). When aphides that have been feeding on diseased foliage proceed or are transferred to healthy leaves, they infect the latter; and, although no immediate sign that infection has taken place may become apparent, yet when tubers of such plants are used for seed the resulting plants will be found to be affected with Leaf-Roll.

In the field it is believed that aphides are the natural means by which Leaf-Roll is spread, and it is clear that in localities where these insects are prevalent, provided

diseased plants are at hand, spread will be most rapid and most intense. There are some grounds for suspecting that other classes of sucking insects, such as Capsid Bugs and Leaf Hoppers, may play the same rôle as aphides do, but more evidence is required before this can be regarded as fully established. It is believed that Leaf-Roll cannot be contracted directly from the soil, but the problem as to whether transmission from diseased to healthy plants naturally occurs underground through the agency of insects or other means has not yet definitely been solved.

It is important to note, however, that the spread of Leaf-Roll through the agency of aphides is not necessarily confined to the field. It may also occur during storage, particularly amongst seed tubers boxed for sprouting. Aphides not infrequently infest the sprouts of such potatoes in store, and if, after having fed on the sprout of a tuber from a diseased plant, they migrate to the sprout of a healthy tuber and feed there, they may convey infection, and the plant arising from that tuber will then be affected with Leaf-Roll.

As to the nature of the material or substance that is transmitted to and causes Leaf-Roll in a previously healthy plant, little or nothing is at present known. The plant juice which carries the infective principle may be passed through the pores of a filter which holds back all ordinary fungi and bacteria, and yet retain its power of infectivity. The active principle is at present generally referred to as a *virus*, and if—as there seems some reason to suppose—the virus is some kind of organism, the dimensions of the latter, during part of its life cycle if not during the whole of it, must be ultramicroscopically small. It may be added that the part played by aphides in transmitting the disease is believed to be a purely mechanical one, and that the virus undergoes no change in the insect's body. In its search for food from its host plant an aphis reaches with its proboscis the phloem or bast of the vascular tissue, that is, just the tissue usually regarded as being devoted to the conduction of manufactured plant food. The fact that this particular tissue becomes disorganized in plants affected with Leaf-Roll is significant, and suggests that the intimate association of the virus with the phloem is of considerable importance in this disease. When once inoculated into the plant the virus sooner or later permeates the whole of it, and for this reason Leaf-Roll is to be regarded as a systemic disease.

Measures of Control.—There is no known cure for Leaf-Roll, and the only certain means of avoiding it is to ensure that none but tubers from healthy plants are used for seed, and that the plants arising from them are protected from extraneous infection during growth.

The following are some of the measures to be adopted in controlling Leaf-Roll disease, and they apply to other potato degeneration diseases, such as Mosaic, Crinkle, &c. :—

1. *Rejection of all Infected Plants for Seed Purposes.*—Since the disease is perpetuated by means of the seed it is of the utmost importance that no seed should be saved from affected plants. Not only should tubers from dwarfed plants and from plants with obviously rolled foliage be rejected for seed purposes, but so also should tubers from all plants showing rolling in the lower leaves only and—at all events in the south—those from even apparently healthy plants in proximity to diseased ones.

In gardens and small holdings, the common practice of allowing the entire crop of healthy and diseased plants to mature and then selecting tubers of seed size from the produce cannot be too strongly condemned. No seed should be saved from any crop which shows any considerable proportion of plants suffering from Leaf Roll.

2. *Roguing and Early Lifting of Seed Crops.*—Where potatoes are specially grown for seed purposes, thorough roguing of the crop each season should be made a definite routine practice. This should be begun as early as possible, that is, as soon as diseased plants become definitely recognizable, since in some seasons aphis transmission begins early. It should be repeated when necessary. By this means the centres from which infection is carried can be suppressed. If the work be done before any new tubers have been formed, no digging will be required, the plants, with the seed piece, being simply pulled up and destroyed.

Although, as already explained, the disease is a systemic one, a certain period of time—it may be a very short one—must elapse subsequent to inoculation with the virus, before the latter reaches every part of the plant. By early lifting, therefore, it may be possible to secure some healthy tubers from recently infected plants. There is no doubt that thorough and persistent roguing begun early, together with early lifting are the most important factors which are likely to contribute to success in obtaining and keeping seed free from Leaf-Roll.

3. *Special Precautions in the South.*—In the southern and drier counties special care is required as to seed. In fields and large plots, if healthy northern seed has been used and the crop is entirely free from Leaf-Roll, seed may usually be saved safely for one season, and a good crop be the result in the following one. If Leaf-Roll appeared, however, even to a slight extent, no seed should be saved unless the crop was promptly and efficiently rogued, since an increased

(*Photo* *P. A. Murphy.*)

Potato Leaf-Roll in "Golden Wonder," showing rolling confined to the lower leaves. Tubers from such plants should not be used for seed purposes as they will give rise to diseased plants and will yield a very poor crop.

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FIG. 1.—COMMON SCAB OF POTATOES.
[*Photo: Reproduced by kind permission from Leeds University Bull. No. 118.*]

amount of disease will be evident in the following season. In small gardens and allotments where the risk of transmission from diseased plants situated in neighbouring plots is exceedingly great, seed should never be saved, but a fresh healthy stock should be obtained each year from a reliable northern source.

4. *Control of Aphides.*—Control of aphides in the field to such a degree as to render Leaf-Roll transmission by them inoperative is impracticable. Where, however, aphides infest sprouting potatoes they may be suppressed by exposing the tubers in their sprouting boxes to a fumigant in a closed room or store. Good results are reported from the use of tetrachlorethane. This liquid may be employed at the rate of about half-a-pint per 1,000 cubic feet space. It should be distributed in saucers on the floor, and the room or store is then tightly closed for two or three days, at the end of which time the aphides will be dead. On opening the store it should be well ventilated to get rid of the tetrachlorethane vapour before work is commenced in it.

POTATO SCAB.

Common Potato Scab or Brown Scab is one of the most widespread diseases affecting the potato. It is particularly prevalent on light gravelly soils poor in humus, and on other soils where ashes, lime and other alkaline substances have been used freely.

Although not so serious as in some potato diseases, the losses caused by Scab are not by any means as insignificant as might at first sight be imagined. As a commercial article the tubers are rendered unsightly and their market value is considerably depreciated. The consumer also suffers as, owing to the deeper peeling which is necessary, there is excessive waste of the best part of the potato. Further, affected tubers when stored are more liable to be attacked by fungi and to decay than those with sound skins.

Cause of Scab.—It is only comparatively recently that the true nature of Scab has clearly been defined. Great confusion existed in the past owing to the fact that ordinary Brown Scab was attributed to mechanical injury, or to the effect of various irritating substances in the soil. It is now known that these substances are not the cause of it, for experiments have shown that soil which has been sterilized will not produce scabbed potatoes, however full of ashes, road sweepings or other irritating matter it may be.

Scab is now known to be caused by the attacks of minute fungi belonging to a group known as the Actinomyces. At one time it was supposed that all Common Scab was caused

by a single species of the genus, to which the name *Actinomyces scabies* was given. But recent research has shown that more than one species may attack the potato; and, indeed, it seems probable that the varying form of the scabs themselves, such as superficial scab, deep scab, &c., may, at any rate to some extent, be due to the action of different species. The general results of the attacks of these organisms are, however, very similar. In response to the irritation set up by the organism the growing tuber develops loose corky tissue at the infected spots instead of normal smooth skin; and thus the scabs are produced (*see* Fig. 1 and 2). There is an attempt on the part of the living tuber to exclude the invading organisms, and this is, as a general rule, successful since the parasites are confined to the more or less superficial layers so that the internal tissues of the tuber remain unattacked. When the tuber has completed its growth and is separated from its parent plant the production of scabs ceases.

The Influence of Soil Conditions. — Scab-producing organisms are very widely distributed in cultivated land, and are, indeed, normal inhabitants of the soil. As stated above, attacks of Scab are particularly severe on two classes of soil (1) those of a sandy or gravelly nature, poor in organic content, and (2) alkaline soils, or those which have become alkaline through the addition of lime, ashes, and soot, or through an unbalanced use of fertilizers.

It is clear, therefore, that remedial measures should aim at changing those conditions of the soil which tend to favour the disease. In other countries, disinfection of the seed has been advocated, but, in view of the abundance of the scab-producing fungi in most soils, this treatment, except in special cases would appear to be useless.

The importance of humus or other organic matter in preventing severe attacks of Scab, has recently been investigated by Mr. W. A. Millard, of the Department of Agriculture, University of Leeds.* In a valuable and well illustrated report he shows the striking effect of applications of grass mowings, or other green organic matter, on land known to produce severe scabbing.

Methods of Control.—The most important preventive measure is suitable treatment of the soil.

(1) *Treatment of Sandy or Gravelly Soil.*—Organic matter of a vegetable nature should be applied. On farm lands this is best done by ploughing in a green crop. In gardens and small holdings decayed leaves, spent hops and grass mowings

* Univ. of Leeds Bulletin, No. 118, 1921.

FIG. 2.—COMMON SCAB.—A potato showing the typical appearance of individual scabs.

[*Photo: Reproduced by kind permission from Leeds University Bull. No. 118.*]

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Potato tubers affected with Dry Rot. Note the characteristic wrinkling of the skin and the development of fungus pustules on the attacked parts.

may be used. Grass mowings particularly have given excellent results. These should be dug in immediately previous to planting, at the rate of ½ to 1 barrow-load to 4 square yards, or 10-20 tons (weighed green) to the acre, according to the nature of the soil and the intensity of the attack. An alternative method consists in spreading the grass in and around the trenches when planting the potatoes and covering it in during the operation of earthing up. Care should be taken, however, to avoid "overheating" of the "sets."

(2) *Treatment of Alkaline Soil.*—The application of lime, ashes and soot should be avoided on alkaline soils, and their alkalinity counteracted by the use of superphosphates of lime and sulphate of ammonia. In small gardens and allotments a dressing of flowers of sulphur at the rate of 1 ounce per square yard may prove beneficial. The effects of the above treatment may not be fully noticeable until after the first season.

(3) *Seed.*—The eyes of badly scabbed tubers are apt to be injured, and hence such tubers should not be used as seed.

(4) *Sanitary Precautions.*—Scabbed potatoes and peelings from affected potatoes should not be thrown on the manure heap, nor, unless previously boiled, should they be given to pigs.

DRY ROT OF POTATOES.

All growers of potatoes are probably more or less familiar with Potato Dry Rot and with the serious losses to which it sometimes gives rise. The disease, which is caused by the fungus *Fusarium caerulcum*, attacks the tubers during storage and causes their decay. It usually develops from December onwards, becoming more severe as the spring advances, and, in certain first early varieties, it may cause losses of 50 per cent. amongst seed tubers. It does not attack the potatoes while they are still in the ground, nor is it known to produce a "wilt" or more or less gradual death of the haulm, such as occurs in diseases caused by certain allied species of Fusarium in America.

Description.—In the earliest stages of attack, Dry Rot appears as a superficial patch that is darker in hue than the surrounding skin and somewhat sunken. As the diseased area increases, it becomes corrugated or wrinkled in irregularly concentric rings and shrinks considerably (*see* figure). Pustules of the fungus then begin to burst out through the skin whilst, as the disease proceeds, the internal tissue of the potato becomes brown and shrunken, leaving cavities inside, often filled with fluffy mycelium.

The pustules are white in appearance, though they may become pinkish if developed in a good light. If the soft white or pink exterior be rubbed away the base of the pustule is found to be bluish, hence the name *F. caeruleum.** The blue colour is also sometimes well seen in the mycelium which flourishes in the internal cavities. A microscope shows that the pustules consist mainly of dense masses of spores. These spores are long and colourless, more or less sickle shaped, and divided by cross walls into a varying number of cells, usually four.

In bad cases the rot continues until the potato becomes hard, dry, and quite light in weight. If the attack commences very late or makes but slow progress, the tubers survive until planting time and commence to sprout. Such tubers if planted generally die and produce no plants at all, but they may grow and develop small though healthy plants. Failure of planted seed tubers to produce plants (especially in early varieties) is frequently due to Dry Rot having been present.

Causes leading to Attack.—Dry Rot may start at any point on the tuber, and is not particularly associated with the "heel" or stem end of it. It most frequently starts from a wound, a broken surface offering an ideal place of entrance for the fungus. The extensive losses that sometimes occur are nearly always traceable to bad handling or excessive bruising during transport. Tubers which have been badly rubbed in sacks often become severely attacked after some weeks in storage. Wounds, however, are not essential, for it has been proved that potatoes with unbroken skins can also be attacked. In such cases the disease usually starts at an eye or a lenticel (breathing pore).

The maturity of the tuber has a considerable influence on its susceptibility to infection; the more mature the tuber is and the nearer it is to the time of sprouting the more easily it becomes infected. It is for this reason that the disease is usually most prevalent in the early months of the year, and seldom causes serious trouble before December.

Susceptibility of Varieties.—Dry Rot is pre-eminently a disease of early varieties. May Queen, Ninety-fold, and Reading Russet are exceedingly susceptible. Sharpe's

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* The species commonly causing Potato Dry Rot in the British Isles is now known to be *F. caeruleum* and not *F. Solani* as was formerly supposed. The name *Nectria Solani* which has been much used in the past, is erroneous. It should be understood that other species of Fusarium may occur on diseased potato tubers in this country, but these are usually saprophytic and quite distinct from *F. caeruleum*. They are of common occurrence following Blight.

Express and Duke of York also suffer severely, but others, such as Epicure, are fairly resistant. Late varieties are sometimes attacked, but, as a rule, only to a minor extent.

Measures of Control—1. *Careful Handling.*—In those first early varieties particularly susceptible to Dry Rot special care should be taken as to digging and subsequent handling. *All mechanical injury due to implements, &c., and to bruising in bags should be reduced to a minimum.* The less the tubers are handled the better.

2. *Methods of Storage.*—These varieties should *never be clamped or stored in bins.* The seed should be obtained as early as possible in the autumn, and as soon as it is received it should be transferred direct to the sprouting boxes. Tubers which are boxed in October and greened early are seldom badly attacked by Dry Rot. The storage place should be cool, well ventilated and well lighted, especially during the sprouting period. If Dry Rot appears in the store, the stock of tubers should be examined at once and all affected ones removed. This process should be repeated as frequently as practicable.

3. *Disinfection.*—Where the disease has been very bad it is advisable that the storage boxes and the walls of the cellar or loft should be disinfected or washed down with a 2 per cent. solution of copper sulphate.

4. *Disposal of Diseased Seed.*—Potatoes that are but slightly affected may be fed to pigs or chickens, but only if previously thoroughly cooked. Badly diseased potatoes should be burnt. Cutting out the diseased portions and treating with sulphur or lime does not check the disease.

5. *Importance of Healthy Seed.*—Potatoes attacked by Dry Rot should never be used for seed. Sets cut from potatoes affected with Dry Rot or even from sound tubers which have been in contact with diseased ones, frequently develop the disease through spores lighting on the freshly cut surface, and loss of crop ensues.

THE SCLEROTINIA DISEASE OF POTATOES AND OTHER PLANTS.

The diseases dealt with in this leaflet are caused by the fungus named *Sclerotinia Sclerotiorum*, a well-known parasite capable of attacking a wide range of cultivated plants. The method of infection and behaviour of the fungus have been studied most carefully in the potato and, as the life-history of the parasite and the treatment to be adopted are the same when other crops are concerned, the potato disease only is described in detail.

The *Sclerotinia* disease of potatoes is most destructive in the northern and damper parts of the country. In the west of Ireland the loss occasioned by it is so great that, with the exception of the ordinary potato Blight, it is stated to be the most serious disease with which growers have to contend. The fungus attacks the stem, either near the ground or at some distance above it. Subsequently it penetrates the inner tissues and destroys them so that the stem falls over at the affected spot and dies. Though the tubers are not attacked the yield is reduced owing to the premature death of the haulm, and in districts where *Sclerotinia* is widespread the crop may suffer very severely.

Description and Life-History.—In the earliest phases of attack, usually about the beginning of July, the disease shows itself in the form of white patches of fungus threads or mycelium, on the outside of the stem (Fig. 1).* In contrast to most stem diseases there is little or no yellowing of the foliage except of the hidden lower leaves, with the result that infected plants are for a time easily overlooked. If dull, damp weather prevails the mycelium develops rapidly and begins to form oval or spherical cushions, white in colour, from which minute drops of liquid exude (Fig. 2). These cushions represent the youngest stages of the resting bodies known as *sclerotia*. Each sclerotium consists of a compact mass of mycelium, which later becomes firm, and finally hard and black, though internally it remains white. The sclerotia are spherical or oval in shape, and usually about the size of a pea, but frequently more elongated. When ripe they fall off and remain dormant in the soil until the following spring.

In addition to forming external mycelium and sclerotia the fungus soon penetrates the inner tissues of the stem. The cells are invaded, and the pith-cavity is filled up with fluffy white mycelium in which sclerotia, similar to those produced externally, develop (Fig. 3). The latter remain inside the stems, but ultimately reach the soil if the stems are allowed to decay on the land. The attack on the stem, which is more or less localized, is a somewhat rapid one. As a result the tissues at the place of infection are quickly killed, and the stalk topples over, usually whilst the leaves are still green. Since this may happen as early as July the very serious nature of the disease in these circumstances will be evident.

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* For the illustrations in this leaflet the Ministry is indebted to the late Department of Agriculture and Technical Instruction for Ireland, now the Department of Lands and Agriculture, Irish Free State.

FIG. 1.—SCLEROTINIA DISEASE. A stalk attacked in two places, at one of which fracture has occurred.

FIG. 2.—The white bodies on the surface of the stalks are immature sclerotia.

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FIG. 3.—SCLEROTINIA DISEASE. Three potato stalks split open

FIG. 4.—A single sclerotium which, after lying dormant during winter, has produced a spore-bearing cup or apothecium (nat. size).

The fate of the sclerotia in the soil has been carefully studied by several observers. They remain dormant until early summer of the following year, when they germinate and give rise to small disc- or cup-shaped bodies which produce spores (Fig. 4). The cups are borne on slender stalks, and appear just above the surface of the soil. They are pale, brownish yellow in colour and from one-quarter to one-half an inch in diameter. When ripe the cups discharge spores into the air, usually in large numbers at a time. If they are carefully watched, smoke-like puffs of spores may be seen arising from them. The intermittent discharge of spores from a single cup may continue for two or three weeks. These spores germinate readily and produce mycelium which thus completes the life-cycle of the fungus.

Method of Infection.—It was a for a long time thought that potato plants became infected solely by vegetative mycelium present in the soil, but investigations carried out in Ireland have shown that infection is also brought about by air-borne spores derived from the cups. The spores are blown about and alight on the foliage. On germination they are capable of infecting the older and fading leaves, and from the leaf the fungus passes to the stem. In some cases direct infection of young healthy tissues apparently also takes place, especially in parts of the plant such as leaf axils where moisture accumulates.

It was for a long time supposed that this fungus produced spores of a second kind; that, in fact, the common mould, Botrytis, which also produces sclerotia, was a stage in its life history. But this idea has now been disproved. The sclerotia of this Botrytis differ from those of Sclerotinia, and they do not give rise to the cup-shaped fructifications (*apothecia*) which are produced by the latter fungus. (*See* p. 74.)

Infection of other Crops.—As mentioned above many other cultivated plants are attacked by *S. Sclerotiorum*, of which the following are amongst the most important:—Tomato, artichoke, sunflower, paeony, bean, marrow, and cucumber; and, in storage during winter, carrot, turnip, and artichoke. Though the actual mode of attack has not been fully studied in most of these plants, it is safe to assume that infection takes place by means of spores or by mycelium derived from a spore, though infection by mycelium produced directly from sclerotia may, perhaps, also take place. In most cases spore-infection probably occurs, as in the potato, through old leaves or wounded surfaces, though under conditions of exceptional moisture direct infection of healthy tissue also may be expected. In all cases sclerotia are produced in abundance. These fall to the

ground or remain in the dead tissues of the plant, where they lie dormant till the spring, when they germinate or form spore-cups in the usual way. The disease seldom appears before midsummer, and it is favoured by warm damp weather.

Methods of control.—1. *Removal of Diseased Plants.*—The most important measure to adopt where practicable is to collect and burn all diseased portions of the plant promptly and systematically in order to prevent the disease from spreading and also to prevent the sclerotia from reaching the soil. If this is carried out thoroughly, the number of spore-bearing cups produced in spring will be largely reduced.

(2) *Sterilization of Soil.*—For greenhouse or garden work sterilization of the soil by steam may be recommended.

(3) *Change of Site.*—Unless the soil has been sterilized, plants liable to be attacked by Sclerotinia (see preceding page) should not be grown again for at least three years in soil which has carried a diseased crop. The fresh site selected should be well removed from the old one.

(4) *Late Planting.*—With potatoes, in the west of Ireland, late planting has proved successful to a certain extent, the explanation being that fewer old leaves (which provide the fungus with an easy means of entry) are available at the time of the main spore-discharge.

(5) *Storage.*—When root crops such as carrots and artichokes are concerned, the store should be looked over repeatedly, and all diseased or damaged roots should be removed and destroyed. A sprinkling of a mixture of lime and flowers of sulphur in equal parts is sometimes recommended in order to check the spread of the fungus.

MOSAIC DISEASE OF POTATOES.

Although the disorder of potatoes termed Mosaic* has only recently been regarded as a specific disease, there is evidence that it has been in existence for very many years. At the present time it is found in potato crops all over Europe and also in North America; and, since the disease is distributed by means of the seed-tubers, it probably occurs wherever the potato is grown.

Potato Mosaic in Britain.—No general or well-known popular name for the disorder exists, but it is clear that the terms "miffy" and "miffiness" in common use in certain

* A fuller account of the disease will be found in the *Journal of the Ministry of Agriculture*, July, 1921.

districts is usually, if not always, applied to potato plants affected by Mosaic, and that the mosaic symptoms are more or less known to observant growers. It is also clear that what is spoken of in the south of England as "deterioration" in potatoes is, at times, only the result of a general attack of Mosaic disease.

The disease occurs in varying intensity in all parts of the British Isles, and is frequently responsible for light crops on farms and, to an even greater extent, in gardens and allotments.

Description of Potato Mosaic.—The symptoms of the disease vary somewhat, both in different varieties and in different parts of the country, but the following account will probably enable the reader to recognize Mosaic.

The most obvious and distinctive character, and the one from which the disease takes its name, is the mottling of the foliage. The individual leaflets, instead of presenting a normal uniformly green appearance, are faintly mottled or "mosaicked" in varying shades of green. Coupled with the mottling is usually a crinkling of the foliage, a waviness in the outline of the leaflets, and other indications that the leaves are not normal. In some varieties and in severe attacks this crinkling or puckering becomes very marked. Under certain conditions, especially if it develops late in the season, this mottling of the foliage may be very conspicuous, but the plants may appear otherwise healthy and produce a good or fair crop of tubers.

In more severe attacks other symptoms are apparent. A dwarfing tendency is very frequently manifested, and when this takes place there is a marked reduction in the yield. In extreme cases the growth of the plants may be completely stunted, and when this stage has been reached the crop is reduced to practically nil.

The mottling appears to be materially modified by climatic conditions. In cooler and damper regions typical mottled foliage may be found throughout the entire season, but in the hotter and drier parts of the country this feature, though quite apparent earlier in the season, may become much less marked later, and may even disappear; the crinkling of the foliage, however, remains.* It would also appear from certain experiments that, though the typical mottling is more *conspicuous* in the north the *effect* of the disease may be more serious in the hotter parts of the country.

* The mottling symptoms are more clearly seen on a dull day or when a shade is thrown over the plant. A white sheet of paper held under the leaf also assists in throwing the mottling into relief.

Intensity of the Disease and Effect on Yield.—The intensity of the attack varies greatly. In general the effects of the Mosaic disease are more severely felt in the drier and warmer parts of the country. Owing to the Mosaic disease having only recently been recognized in England, few precise records exist as to the effect of the disease on the yield. It is probable that in most parts of Scotland and in the cooler and damper parts of England and Wales the diminished yield due to the disease is relatively slight. In the warmer and drier parts of England, however, there is evidence that the reduction is more marked. Under average field-conditions affected plants appear to show a decrease in yield, as compared with healthy plants, of from 15 to 35 per cent. In gardens and allotments where local or home-saved seed is used, the very dwarf form of the disease frequently occurs and the losses are very much more serious.

Transmission of the Disease.—It has been clearly established that Potato Mosaic is carried from season to season in the "seed" tuber, and that diseased plants do not recover but their progeny reproduce the disease each successive year. It is also known that Potato Mosaic is transmissible, and healthy plants, if surrounded by, or grown in proximity to, diseased ones, are liable to contract the disease and show it the following season in their progeny. The infective principle is now generally termed a virus and is present in the cell-sap but the exact nature of the virus is not known.

The method by which the infection of healthy plants takes place in nature is similar to that described for Leaf-Roll (*see* p. 54). It has been discovered that the virus is conveyed by aphides (green-fly) which have fed on affected plants.* Where infection takes place early in the season mottling of the newly developed foliage may occur during the same season, but when the plants become infected later, the disease shows itself only in the progeny the following year. On the negative side it may be noted that no infection has been obtained when biting insects such as flea beetles or Colorado beetles have been used, neither is there any evidence that the Mosaic disease is contracted from the soil.

Susceptibility of Varieties.—During 1920 the Ministry undertook a preliminary survey of the distribution and intensity of Potato Mosaic in England, and observations

* The experiments proving this fact were carried out both in the greenhouse and in insect-proof cages in the open. If aphides which had been sucking the juice of diseased plants were introduced into the cages, infection followed; if aphides from healthy plants were introduced, no infection followed.

were also made on the relative susceptibility of the different varieties. It was found that, though the disease occurred to a limited extent in almost all varieties, both early and maincrop,, there was a very marked variation in the percentage of infection commonly present, as well as in the intensity of the attack.

Under field conditions four varieties stood out above others as being specially susceptible. These were *Golden Wonder*, *Langworthy*, *Burnhouse Beauty and Tinwald Perfection.* In these varieties, affected plants to the extent of 30 per cent. of the crop and upwards were commonly found in many parts of the country, whilst in some fields 75 or even 100 per cent. showed the disease. It should be noted that the first two varieties mentioned are of good quality but are well-known to be particularly light croppers; and there can be little doubt that this peculiarity is due to the very general presence of Mosaic disease. Other varieties considerably infected with Mosaic were *Arran Chief*, *Boston Kidney* (*Dargill Early*), *Irish Chieftain* and *King Edward.*

Measures of Control.—The two points to be clearly grasped are (a) that infected plants do not recover, but carry the disease from season to season by means of the tubers; and (b) that by reason of aphis attacks the disease is transferred from infected plants to healthy ones and asserts itself more prominently the following season. The following preventive methods should therefore be observed:—

(1) Seed tubers should not be saved from diseased plants, or from plots or fields where the disease is present in any quantity.

(2) In the south where the disease not only occurs in more severe form, but is apparently more liable to spread (probably owing to earlier and more extensive attacks of aphides) extra care should be taken as to seed. Where the disease occurs no seed should be saved, but fresh seed should be obtained from a good district in the north of England or from Scotland or Ireland.

(3) Where Mosaic is persistently troublesome, varieties particularly subject to the disease should not be grown.

(4) Early roguing is of some value, but under ordinary farm or garden conditions the results are hardly commensurate with the cost. When new varieties or seedlings are involved the matter is different, and special methods are warranted. In such a case if roguing is carried out with extreme care and thoroughness, and if aphis attacks be prevented by spraying

with a good insecticide (such as nicotine and soft soap), complete success should be possible. With valuable crosses the use of aphis proof cages might be considered.

(5) Those who grow for wholesale seed purposes should remember that, though the effect of Mosaic may be comparatively slight in the north, it is often more severe in the south, and, as the disease becomes known, the demand for seed free from Mosaic will increase. Disease-free stocks, therefore, should be retained and worked up for seed purposes. With new varieties it may pay to isolate them from other stocks, rogue carefully, and even spray with soft soap and nicotine in the summer months.

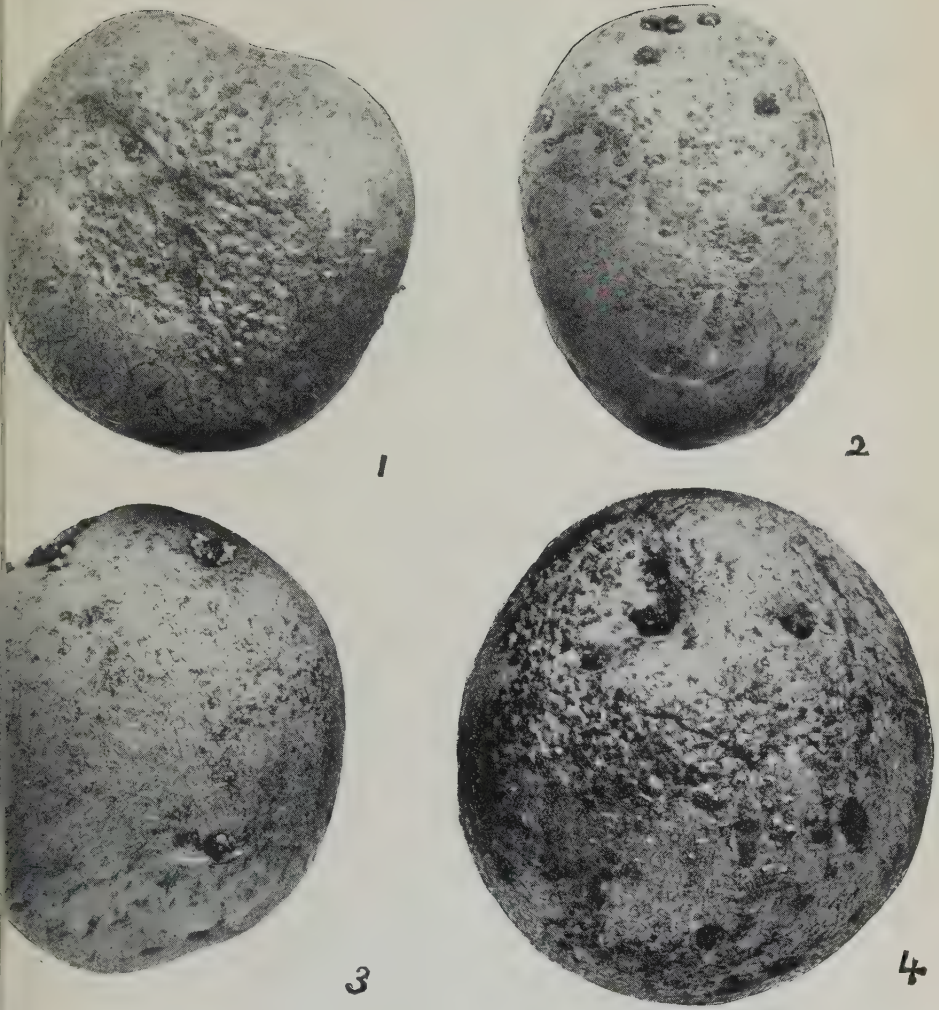
SKIN SPOT.

Skin Spot is a disease that affects potato tubers in storage and is chiefly important in that it is capable of causing considerable damage to the eyes of seed potatoes. The disease is due to the minute fungus *Oospora pustulans* which produces small spots or pimples over the surface of the tubers. Though the life-cycle of the fungus is not fully known it is believed that it gains access to the tubers from the soil and develops extensively only under the conditions provided by storage.

The external characters of Skin Spot, although not very striking are quite distinctive, and there is little likelihood of confusing it with other spots or scabs (*see* Fig. 1-4). Nevertheless, it has been suggested in America that Skin Spot is merely an incipient or inhibited condition of attack by Spongospora, the organism which causes Powdery Scab. This suggestion stimulated further research in this country and it has been shown that there is no connexion between Skin Spot and Powdery Scab.

The spot assumes a slightly different form according to the variety of potato on which it occurs. In the coarse-skinned varieties, such as Arran Chief, definite pimples are developed which, when dry, are very similar in colour to the normal skin, but when wet they stand out as a darker brown. In the smooth-skinned varieties, such as King Edward, the diseased areas are scarcely raised, but consist of small, dark, circular spots with a slightly raised centre, the area being brown or black in colour. Often the spots or pimples occur so close to one another that they merge and thus extend over a considerable area. During later stages the pimples may become ruptured and thus give the appearance of small scabs.

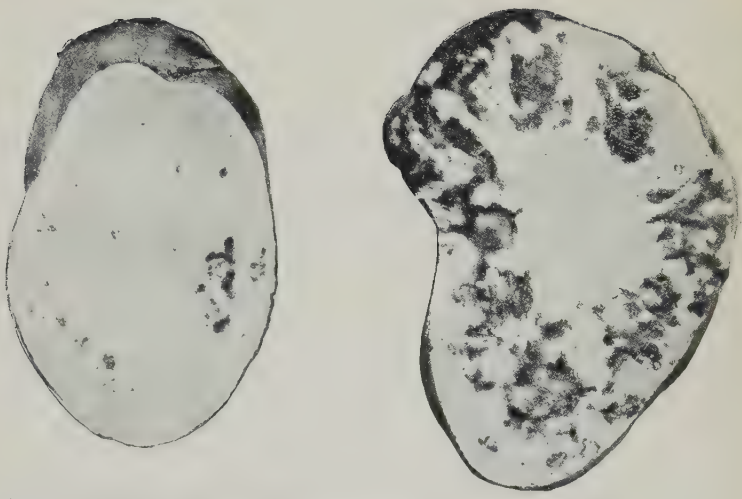
With regard to the damage caused by Skin Spot, the fungus is confined to the surface layers and is usually sharply isolated from the mass of the flesh by a layer of



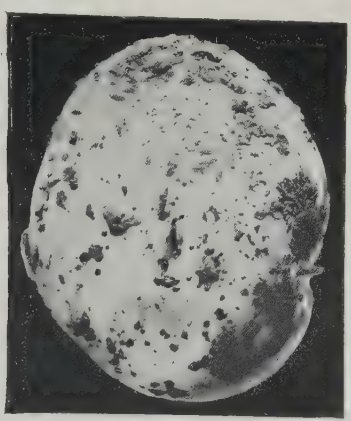
Spot.—Affected potato tubers.

1, 3, 4, Arran Chief ; 2, British Queen.

[*To face page* 72.



Spraying. Showing a mild and a bad attack. Variety.—Kerr's Pink.



Black Scurf Fungus.—Showing scurfy masses of mycelium (*Sclerotia*) on the surface of the tuber.

cork cells. In ware potatoes, therefore, the actual damage is slight and, as the spots are superficial, there is little or no waste in peeling. When very severely spotted and disfigured, however, even ware potatoes may be depreciated in value. With seed potatoes the matter is different. When there is much infection or the spots are closely crowded together, there is a great danger of the eyes being injured. If the eyes are not affected the shoots will grow and the plants will yield a normal healthy crop, but where the eyes are infected they are often severely injured and even killed. The planting of such seed leads to misses in the crop.

Although the primary buds in the eyes may be killed, it sometimes happens that secondary buds develop. On account of the check at the start, however, the plants are late and the yield is reduced. Though these secondary buds are developed fairly frequently, it should be remembered that many eyes are killed outright and that it is therefore highly undesirable to plant badly spotted tubers.

Control Measures.—Although the disease has appeared on seed grown in Lincolnshire and Yorkshire and is often very abundant on Scotch seed, the nature of the soil in which it is most prevalent and the conditions of storage which favours its development are matters which still await investigation, and no recommendations can at present be made. The only advice which can be given is to avoid planting badly affected tubers.

SPRAING.

Spraing is not a generally distributed disease, but is well known and troublesome in certain localities where the soil conditions appear to favour its development. The disease may be recognized by the appearance of dark brown blotches or streaks in the flesh of the tuber (*see* Fig.). No fungus is present in the discoloured areas and the cause of the disease for long remained uncertain, but recently it has been shown that a bacterial parasite is perhaps responsible.

The blotches somewhat resemble those of ordinary Blight but are generally smaller and irregularly scattered through the flesh, instead of occurring immediately under the skin. They commence, moreover, as greenish translucent spots, rather than as reddish brown areas as in Blight, though they become brown later. The diseased patches can sometimes be traced to lenticels on the surface of the tubers, thus indicating that the parasite found its way into the tuber by way of these structures.

The severity of the attack varies greatly. In some cases the infection may be so mild as hardly to affect the tuber for edible purposes. In others it is very severe, as shown in the illustration. The disease is said to be much more prevalent in stony or gravelly soil and to be more severe in dry seasons. Certain varieties also appear to be more susceptible than others.

Control Measures.—So little is really known as to the conditions under which Spraing arises that it is not possible to suggest remedial or preventive measures. Experiments have shown that potatoes affected with Spraing do not produce a crop similarly affected when grown in good land, consequently a mild amount of Spraing in seed potatoes need not cause serious alarm. The type and condition of soil appears to be the main factor in the development of Spraing, and soils which are known to produce potatoes affected with this disease are best used for other crops.

BOTRYTIS DISEASE.

The fungus *Botrytis cinerea* which is very common on *dead* vegetable matter, becomes, under certain conditions, parasitic and attacks living tissues. In the wetter parts of the country, and in damp seasons especially, it frequently causes damage to potato plants.

The spores of the fungus germinate as a rule upon old dead leaves and from these it spreads to the sound tissues, but during spells of warm, damp weather direct infection of young healthy foliage occurs. In this case the disease shows itself as brown, dead areas usually at the tips of the leaflets. The mycelium (or fine filaments of the fungus) rapidly destroys the tissues, and, growing through the leaf-stalk, enters the stem, whence it proceeds in a downward direction, killing the outer tissues and involving also the loss of other leaves. In many cases the attack is slight and a small portion of the stem and a few leaves only are affected, but with continued wet weather it is more severe and the whole of the shoot dies and turns brown. The tubers themselves are not invaded by the fungus but the yield may be lowered if the attack on the foliage is severe. A greyish mould develops on the surface of diseased leaves and especially on those which fall off or are near the ground. The mould represents the fruiting stage of the *Botrytis* fungus which consists of myriads of spores borne in minute heads. These spores are dispersed by wind and rain, and, germinating at once, rapidly spread the disease.

After the spore-phase the fungus forms sclerotia which, later in the season, appear as small, flat, black structures

on the dead, blanched stems. The sclerotia, which are resting bodies, produce crops of spores in spring similar to those found on the leaves and stems, and in this way the life-cycle of the fungus is completed. They do not produce cup-like fructifications (*apothecia*) as those of Sclerotinia do. (*See* p. 67.)

Control Measures.—In districts where *Botrytis* is troublesome special care should be taken to avoid overcrowding. When planting in spring sufficient space should be allowed both between the sets and between the rows.

Varieties which are resistant to ordinary Blight have been found resistant also to *Botrytis*, hence such varieties should always be selected.

In order to lessen the chances of re-infection in spring, old diseased stems bearing sclerotia should be collected and burnt before the crop is lifted.

BLACK SCURF OR COLLAR FUNGUS.

Potato tubers frequently show on their surfaces the presence of small compact masses of fungus mycelium, at first pale and chalky, but afterwards dark brown or black in colour (*see* Fig.). The bodies are formed of a mass of almost invisible strands of similar brown fungus filaments and they represent sclerotia or resting bodies found so frequently amongst fungi. This fungus has long been familiar in the literature of plant diseases as *Rhizoctonia Solani* and the disease has been termed Black Scurf. It is now known, however, that this brown mycelium is merely the subterranean portion of what was once thought to be another fungus named *Corticium Solani*, which often occurs as a thin white incrustation at the bases of potato stalks. The latter is the perfect or fructifying stage of the fungus, and is known as the potato Collar Fungus.

Neither the Black Scurf stage nor the Collar Fungus stage appears to cause much damage under ordinary conditions in this country. The sclerotial form is exceedingly common, but the sclerotia, though causing disfiguration, are quite superficial and can be easily removed with the finger nail. Contrary to what has sometimes been stated, this fungus does not cause a rot of the tuber. The mycelium, however, occasionally causes damage by attacking and injuring the young sprouts before they come above ground in the spring thus causing misses. In addition, under conditions unfavourable to vigorous, sturdy growth, the underground portions of young potato stalks may be so severely attacked that the shoots wilt and die. This kind of trouble occurs most frequently in land too frequently cropped with potatoes and can be avoided by proper rotation of crops.

VIOLET ROOT ROT.

There is another soil fungus related to the last, which is a much more dangerous parasite. It attacks the fleshy roots and crowns of many plants, and occasionally the tubers of the potato. It is known as *Rhizoctonia Crocorum*, and its spore-bearing stage has recently been discovered with practical certainty to be the fungus known as *Helicobasidium purpureum.* It is possible that several distinct varieties or strains may exist. On the potato tuber the fungus forms a loose, violet-coloured mycelium which spreads completely over the surface, and forms innumerable sucker-like bodies which penetrate the skin and bring about the partial or total destruction of the flesh.

Control Measures.—The fungus is, fortunately, not common in Britain, but when it occurs it is difficult to eradicate. Chloride of lime (bleaching powder) applied to the soil has been tried with a certain amount of success, but further investigations are needed. Diseased tubers should be collected and burnt, and soil likely to be contaminated should not be used for potatoes, root crops, lucerne or clover.

PINK ROT.

The disease known as Pink Rot is common in potato tubers in parts of Ireland, especially in the west, where it is often the cause of very serious losses which are often more considerable than those due to Blight. It also occurs in England and Scotland, but in these countries it is comparatively rare at present.

Pink Rot starts when the potatoes are still in the ground attached to the parent plant,, and has been found in some varieties as early as July. In most cases the attack begins at the " heel " end of the tuber, and proceeds rather quickly towards the " rose " end. Diseased tubers remain comparatively firm, but if pressed exude a quantity of juice and finally become completely rotten. This exudation also occurs naturally from the parts of tubers that are attacked, and in consequence of it particles of soil become stuck to the surface of the tuber and are conspicuous on lifting. A characteristic series of colour-changes takes place when affected tubers are cut open and exposed to the air. The pink colour begins to show after a few minutes, and within half-an-hour the whole of the diseased portion becomes a deep salmon-pink. With an exposure of several hours the cut surface gradually darkens and becomes purplish-brown or nearly black. It must not, however,, be understood that the development of a pink coloration on cutting open a potato tuber is necessarily a sign of the Pink Rot disease.

A more or less distinct pink colour develops occasionally in perfectly healthy tubers of some varieties when they are cut and exposed to the air. Moreover, a pink coloration sometimes develops in tubers attacked by the Black Leg organism. The rot due to Black Leg, however, is easily distinguished from Pink Rot. In the former the tissues become reduced to a semi-liquid pulp, and cavities are often produced in the tuber. In the latter the tissues remain compact and no cavities are formed.

Plants infected with the pink rot fungus also show indications of unhealthiness in the foliage, due to the presence of mycelium in the stem and roots. This occurs generally rather late in the season. The leaves become pale green or yellow, and the symptoms are those of the wilt type.

Pink Rot is caused by a fungus known as *Phytophthora erythroseptica* which is allied to the Blight fungus, *P. infestans*. Unlike the latter, however, which produces its spores on the overground parts of the plant so that they are scattered by air currents and thus serve to establish epidemics, the spores of *P. erythroseptica* are formed in the underground parts of the plant. There are two kinds of these spores, the most important being thick-walled sexually formed oospores or resting spores. On the decay of the attacked parts of the plant these spores remain in the soil to contaminate it. Pink Rot is, therefore, a disease contracted from the soil, and it becomes of serious import only where proper rotation of crops is deliberately neglected or impossible.

There is comparatively little danger of the spread of this disease through seed tubers. Tubers once attacked quickly rot, and do not survive till the following season. Healthy tubers produced in contaminated land might carry oospores of the fungus in the soil adhering to their surface, but the risk of spread of the disease in this way is slight.

VERTICILLIUM WILT.

This malady of potatoes has been generally recognized in the British Isles only since 1916. The disease is distributed in the seed, and during recent years has been observed to be locally prevalent in several parts of England, being responsible for the premature death of the haulms and for light crops. The disease is caused by a fungus known as *Verticillium albo-atrum*. This fungus invades the wood vessels of the stem and root and causes a more or less premature death of the plant owing to the water-conducting vessels being choked with mycelium, and also, probably, owing to the production of a toxic substance which is carried to the foliage. Infected plants are often

stunted. In some cases affected plants die off gradually, but in light soils and in dry weather they may flag and the symptoms are those of a wilt disease. The disease can be identified with certainty only by verifying the presence of the fungus in the plant.

The life cycle of the fungus is as follows:—In the living tuber, the mycelium is found only in the vascular bundles, and it is confined in them to the wood vessels. With the sprouting of the tuber it passes along the vessels into the new shoots, though sometimes not until the latter have made considerable growth. In later stages the mycelium may advance up the shoots into the wood vessels of the petioles and leaves, though in cases of bad infection the water-conducting tissues become so blocked that the plants wither and die off early in the season. From the base of the haulms the fungus also passes into the underground stems and from these into the new tubers. The mycelium may penetrate well towards the rose-end of the tubers even in the autumn, and during winter it advances further. Affected tubers appear outwardly quite normal, but within they usually show a discoloration of the vascular tissues, especially at the heel end, but the absence of a dark ring in the tuber is not necessarily a proof of clean seed.

Control Measures.—The disease is mainly perpetuated by means of infected seed, but it is practically certain that it may also be contracted through the roots direct from contaminated soil. The presence of the parasite in infected seed can be detected only by expert microscopical examination. The most important preventive measure consists in treating the produce of all infected plants as ware and saving seed from healthy plants only, and from uninfected areas. All diseased haulms and roots should be collected and burnt.

STREAK.

The disease detected in America and elsewhere and described as Streak appears to be present also in Britain. Streak affects the leaves and causes dark, angular spots which often follow the course of the small veins but also invade the soft tissues in between. The spots are visible on both sides of the leaves, and may occur also on the leaf stalks and young stems. In bad attacks the leaf-stalk collapses and the leaf withers, hangs down, and ultimately drops. It has been suggested that the disease is due to a bacterial organism, but no convincing proof of this has yet been obtained and it is more likely that it is one of the virus type like Leaf Roll and Mosaic.

SILVER SCURF.

A fungus known as *Spondylocladium atrovirens* is exceedingly common on potato tubers, and on certain light soils it can, if carefully searched for, be found on practically every tuber. It forms slight blemishes on the skin, often extending over a considerable area. These blemishes occur as discoloured or silvery patches and are more conspicuous in spring, especially on tubers which have become slightly greened. They are often slightly depressed and are dotted over with minute black specks. The latter are sclerotia, which, under suitable conditions, give rise to spores. Occasionally the affected areas become somewhat dry and flake off, but otherwise the fungus appears to cause no appreciable damage.

COLORADO BEETLE.

This beetle—known as *Leptinotarsa decemlineata*, Say., and notorious as a potato pest—was first discovered in the west of the United States where it was living upon a wild plant related to the potato. About the year 1850 it was first noted on potatoes and by 1874 it had spread eastwards across the continent of America to the Atlantic and also northward into Canada. On several occasions it has been carried by shipping to Europe and has even established small colonies which up to the present have been stamped out by the use of drastic measures—as, for instance, at Tilbury in 1901-1902. In 1922 the beetle was discovered in France in the neighbourhood of Bordeaux, about 100 square miles being infested. This is the most serious outbreak which has yet occurred in Europe and it renders great vigilance advisable on the part of potato growers in order to prevent a similar occurrence in Britain.

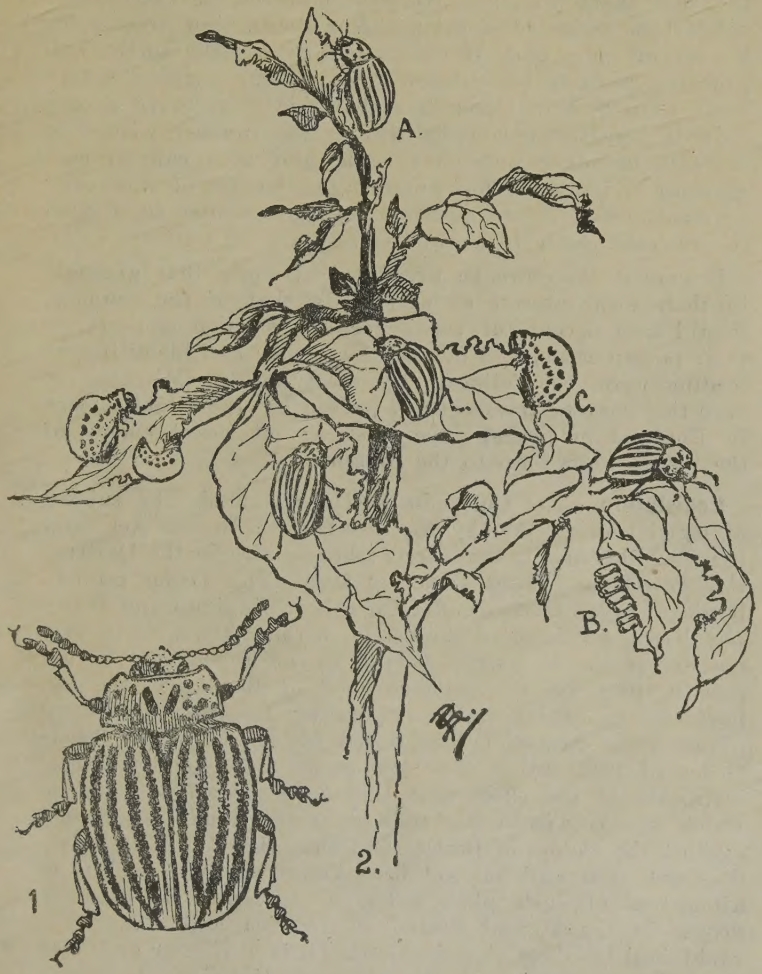
Description and Life-History.—The adult beetles (Fig. 1) are about half-an-inch in length, yellow in colour with five longitudinal black lines on each wing-case—ten lines in all. The winter is spent under the soil, usually about ten inches below the surface, but less frequently the beetles winter among rubbish. When the weather becomes warm in spring or early summer they come out, pair, and the females fly in search of potato plants, tomatoes or such related weeds as Deadly Nightshade, upon which to feed and lay their eggs. As the beetles may become active before the majority of the potato crops are above ground, the insects may be forced to fly considerable distances to find their food. On reaching potato plants they feed on the foliage (Fig. 2. A.) and also lay eggs—yellow and oval in shape—on the undersides of the leaves (Fig. 2. B.). The eggs are laid in clusters

of from ten to forty and in a week or longer, according to the weather, hatch into red-brown larvae or grubs (with six legs but no wings) which eat the potato leaves and grow rapidly, becoming paler in colour, varying from orange to brick-red, and noticeably spotted with black (Fig. 2. c.). The grubs feed for three weeks, probably longer if the weather is cold, and, if numerous, strip the plants of their foliage and even eat the haulm to the ground; they then bury themselves in the soil, where they change to pupae and subsequently to adult beetles. In accordance with the climate there may be one, two or even three generations in the summer. On the approach of cold weather in the autumn the beetles bury themselves in the soil to await the following spring.

The Risk to Britain.—Taking into account the records of the behaviour of the Colorado Beetle in the outbreaks which have already occurred in Europe, it seems only too likely that the insect would find the climate of England congenial and that it would in consequence cause great loss, the nature of which is evident, since a potato plant devoid of foliage or eaten to the ground cannot produce a crop.

As regards the means by which the insects may be expected to reach our shores, it is fairly certain that they cannot fly from Bordeaux, still less from America, and they must therefore come on board ship. In this connexion it is obviously the adult beetles which are to be feared, since they can fly on to vessels or crawl into packages awaiting shipment, and on arrival at an English port they can again fly, if necessary for several miles, until they meet with food. Spring or early summer is the most dangerous period, for the beetle is then most likely to wander and a single female will be sufficient to start an outbreak. On the other hand, beetles arriving in England in autumn are infertile, must wait until the spring, and then the two sexes must meet before breeding can take place, a coincidence which is evidently very unlikely to occur. Still more remote are risks from the introduction of larvae, since for all practical purposes they may be regarded as incapable of travelling for more than a few yards and must therefore be actually placed among growing potato crops if they are to live. The same applies with equal force to eggs. The practical application of this is that no matter what regulations are made to guard against the importation of the Colorado Beetle, some risk must still remain, since no precautions can prevent a beetle from flying on to a ship in America or France and flying off again when the vessel reaches an English port. With the establishment of a colony of the pest so near as Bordeaux this risk is very definite and,

unless the French are successful in their attempts at eradication, it is by no means unlikely that England will have to deal with an outbreak before many years have passed.



THE COLORADO BEETLE.

FIG. 1.—Beetle. FIG. 2.—Damaged potato foliage showing:—(A) beetle, (B) eggs, (C) larva.

Prevention and Control.—Such legislative measures as are possible have been, and will be taken to reduce the chances of the importation of Colorado Beetles and, as these measures must vary from time to time, the Ministry

will issue special notifications. If an outbreak is discovered drastic measures will again be necessary in attempting to extirpate the pest and will probably be successful provided they are taken in time. It will, however, be exceedingly difficult to stamp out a colony after it has been present for a year or more and, if this should occur, the insect will probably have to be numbered among our regular potato pests. Growers will then find that they can obtain a crop only if they spray it twice during the summer with lead arsenate or other poisonous wash, and they can in consequence estimate the loss annually as the cost of two spray applications—a severe addition to the expenses of a crop in any case costly to grow.

It cannot therefore be urged too strongly that growers, in their own interest as well as in that of the country, should keep a careful watch for any suspicious pests on their potato crops, and notably for yellow and black insects feeding upon the foliage. By notifying the Ministry at once they may be the means of preventing the establishment in England of perhaps the most serious insect enemy of the potato known up to the present.

Legislation.—The Colorado Beetle was made the subject of legislation in 1877 by the Destructive Insects Act, and it is included among the insects scheduled under the Destructive Insects and Pests Order of 1922. This Order renders it illegal to land, sell or offer for sale in England and Wales any living specimen of the beetle, without the written permission of the Ministry. Owing to the appearance of the pest in 1922, in the neighbourhood of Bordeaux, the importation into this country of potatoes, tomatoes and living plants from France is prohibited by the Colorado Beetle Order of 1923, unless they are accompanied by an official certificate to the effect that they were grown at a place which is not within a "zone de protection" established against the Colorado Beetle, and that the Colorado Beetle does not exist and has not been known to exist within 40 kilometres of such place. The importation of potatoes grown in the United States of America and Canada is prohibited by the Colorado Beetle Orders of 1924 and 1925 respectively. Copies of the above-mentioned Orders may be obtained on application to the Ministry.

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2 cwts. SULPHATE OR MURIATE OF POTASH.	3 cwts. SULPHATE OR MURIATE OF POTASH.
3 cwts. SUPERPHOSPHATE.	4 cwts. SUPERPHOSPHATE.
2 cwts. SULPHATE OF AMMONIA.	3 cwts. SULPHATE OF AMMONIA.

A Compound Potato Manure should contain 10% pure POTASH.

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